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GEOLOGY OF THE GOUVERNEUR QUADRANGLE

BY

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AND

D. H. NEWLAND

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GEOLOGY OF THE GOUVERNEUR QUADRANGLE

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INTRODUCTION

This report has been prepared, by instruction of the State Geologist, to meet a quite insistent local demand. There is a considerable production of limestone, feldspar, talc, pyrites and zinc blende within the quadrangle limits; a number of people are keenly interested in the mineral development, are actively engaged in prospecting, and greatly desire a more accurate and serviceable areal map of the district than has heretofore been available. Both Mr Newland and myself are under obligation to several of these gentlemen for courtesies of many kinds, freely extended on many occasions.

The Gouverneur district was the starting point from which Professor C. H. Smyth prosecuted his important work on the Precambrian geology of the western Adirondacks, work which did much to establish the fundamental basis of our present knowledge. By all rights of service and of priority in the region he should have prepared this report, and the writer undertook the task with the greatest reluctance and only when it became evident that the work could not be delayed, and that Professor Smyth was not in a position to do it at this time. The areal mapping which is the basis of this report does little more than to reproduce Smyth's earlier results upon a more accurate map of larger scale. The indebtedness of the present work to his can not be made too emphatic.

Doctor Buddington was engaged in mapping the Lake Bonaparte quadrangle, next south of Gouverneur, during the 1916 season. We studied our joint boundary together, to our mutual advantage and pleasure.

The same decline in elevation in a westerly direction continues across the Hammond quadrangle, although somewhat more slowly, the difference in the hilltop altitude across this quadrangle being 300 feet or less, as contrasted with the 400 feet of the Gouverneur quadrangle.

It is quite certain that the hill summits steadily increase in altitude, and it is highly probable that the rate of increase becomes more rapid in that direction, just as it is more rapid on Gouverneur than on Hammond. It is also true that the general relief becomes greater in passing east.

Peneplains

The Adirondack district has an inherent tendency to be elevated, and to move upward rather than downward during times of oscillation of level in the crust of the earth. Such a region is spoken of as positive, to distinguish it from districts of the negative type, whose tendency is to sink rather than to rise. At certain times in the past the margins of the highland have become sufficiently depressed so as to pass beneath sea level and become overspread by marine deposits. The Gouverneur district belongs to this marginal portion, but the central area of the highland seems never to have been depressed sufficiently to carry it below sea level, or rather never since very early in Precambrian time; since then it has had a continuous existence as a land area. From time to time it has been reuplifted, and its surface has experienced much erosion. Between the periodic uplifts long ages of comparative stability have intervened. Slow erosion of the surface by the streams and the rains has been continually going on. During stable intervals the streams cut their valleys to base level, and can cut them no deeper; but after this stage is reached the slow process of valley-widening still continues, and if sufficiently prolonged tends to wear down the entire surface to comparative evenness with comparatively low altitude. Such an erosion plain is called a peneplain. If a peneplained district experiences renewed uplift the streams commence to cut their beds down to the new base level thus created, and the whole erosion process is again set in motion.

The Adirondack district has been thoroughly peneplained certainly twice during its long history and quite likely more than twice. These two times stand out prominently because of the thoroughness of the peneplanation. The earlier of the two was completed in Precambrian time. Then its margins sagged beneath the sea, and upon these depressed margins the early Paleozoic depo its of northern

New York were laid down, beginning with the Potsdam sandstone. These deposits covered and preserved this old erosion surface; but in their turn they have been and are being worn away, and as they disappear portions of the old peneplain surface emerge from beneath and form the present surface, furnishing an exhibit of its characters. Its comparative evenness is surprising when the great variation in resistance to erosion of the rocks composing it is considered.

The entire surface of the Gouverneur quadrangle corresponds to this old peneplain. The scattered patches of Potsdam sandstone are the last vanishing remnants of the former cover of Paleozoic rocks, and they show that the removal of this cover by erosion is the most recent geologic episode of the district, and that the surface of the Precambrian rocks underneath is substantially that which they formerly covered. The altitude of the district is so low, and the time which has elapsed since the cover was removed is so short, that modern erosion has affected the old peneplain surface only in trifling degree. The characters which it possessed when first covered, far back in the remote past, are those which are exhibited on the present surface. It was and is a surface of moderate relief. The more resistant rocks form the elevations, the weaker ones the valleys; the granites and the Grenville quartzites and certain hard gneisses stand above the valleys which are floored by Grenville limestones and certain weak schists. The extreme of relief was and is between 200 and 300 feet. The sky line of the ridge tops is exceedingly even. This Precambrian peneplain was developed over a great area in Canada and New York, and today forms the surface of that portion of the Precambrian which lies near the Paleozoic border.

A much later peneplain, of probable late Mesozoic date, was also developed in the region, and again it was merely the local development of a peneplain which had wide extent in eastern North America. Prior to its development, deformation of the Adirondack region had upwarped the older peneplain into the form of a gentle dome, and at the same time downwarped the margins into shallow troughs, in which early Paleozoic sandstones, limestones and shales had been deposited. The Mesozoic peneplanation truncated the domed summit of the older peneplain; but on the margins of the region the two surfaces intersect and the older passes beneath the younger. The Paleozoic rocks rest upon the surface of the older peneplain, and the younger cuts across them (figure 1). An attempt to illustrate the manner in which, by erosional stripping back of the Paleozoic cover, portions of the old peneplain surface are exposed to view and form the present surface of the marginal portions of the Adirondacks is seen in figure 2.

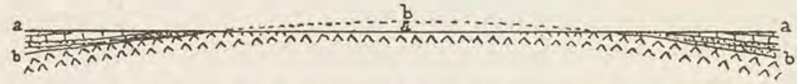


Fig 1. Domed surface of Precambric peneplain, *b b b*, with marginal Paleozoic deposits, both truncated by late Mesozoic peneplain, *a a a*. Vertical scale much exaggerated.

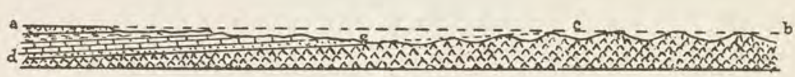


Fig. 2. Diagram in illustration of the manner of reäppearance of the old Precambric peneplain at the present surface; *a b* = late Mesozoic peneplain; *c d* = tipped surface of old peneplain, in part covered by Paleozoic rocks; from c to e, however, the Paleozoics have been recently removed by erosion, reexposing the old peneplain surface; modern erosion has cut valleys in both peneplain surfaces but the ridge summits are remnants of these surfaces

Since the development of the Mesozoic peneplain, the Adirondack highland has experienced further uplifts. These have been most pronounced in the eastern portion of the region, along what is today the chief axis of elevation of the Adirondacks. In the western Adirondacks the elevation has been progressively less, and the concordant hill top elevations of that district are remnants of the Mesozoic peneplain. Still farther west, in the comparatively low district of the Gouverneur quadrangle, the elevation has been but slight. As uplift took place valleys began to be trenched in the surface of the peneplain, and the present ruggedness of the western Adirondacks is due to this valley carving. In the Gouverneur region the whole territory has been worn down below the level of the Mesozoic peneplain, but the surface rocks were Paleozoics, and the modern Precambrian surface is due to their slow stripping away. Since this Paleozoic cover disappeared, the general low altitude has prevented any great depth of valley cutting, resulting in the comparatively small difference in elevation between valley and upland which the quadrangle exhibits.

Pleistocene Deposits

In common with the general region of which it is a part, glacial deposits are scant over the surface of the quadrangle. There are no prominent moraines, no thick accumulations of till; rock knobs abound everywhere, and the valleys are not deeply filled. The larger part of the quadrangle was for a time submerged beneath the bodies of standing water which occupied the general region while the glacial ice was disappearing and after its disappearance. The level of the earlier of these bodies, Lake Iroquois, on the quadrangle today, stands at about 800 feet, so that all of the area except the higher knobs of the wilderness district in Edwards and Hermon, in the southeast corner of the quadrangle, have been washed by its waves. The succeeding marine waters have in like manner wave washed all territory below 475 to 480 feet, and this comprises most of the northwest half of the quadrangle.

Owing to the topography, the shore lines of these bodies of water across the quadrangle were of the highest irregularity, long narrow bays were separated from one another by equally long, narrow promontories, which tailed out into frequent islands. The course of the 800-foot contour across the map will give a good idea of the Iroquois shore, and that of the 480-foot contour an even better one of the marine shore line. The chief effect of these waters was to wash the rock ridges fairly clean of loose rock material which was deposited as valley filling in the depressions between the ridges. The material so washed into the depressions consisted largely of fine clays, and the filling was comparatively even, so that the valley surfaces are now relatively flat, and the rock knobs and ridges rise sharply out of these flats, as though their lower slopes were drowned by the valley filling, as in fact they are.

When Lake Iroquois existed, the larger streams which emptied into it built large sand deltas at their mouths; and the delta of the west branch of the Oswegatchie, formed at that time, is one of the prominent topographic features of the quadrangle. This delta extends from Harrisville (7 miles to the south of the sheet margin, on the Lake Bonaparte quadrangle) nearly to the mouth of the Branch at Hyatt. It is comparatively narrow since the valley is margined on each side by fairly high land, but it will average some 1½ miles in breadth. It is about 10 miles long and its northern 3 miles lie within the Gouverneur quadrangle. Its higher portion has an altitude of 800 feet, which gradually descends to 700 feet at its northern margin. The present course of the river is along the west margin of the delta. The material is a pure, medium-grained sand. Its surface is so much moved about by the winds that vegetation obtains a foothold only here and there, and east and south of Fullerville are wide expanses of this loose, drifting sand. The whole constitutes the comparatively small delta of a small stream. The larger delta of the main river is in Pitcairn township. The great sand plain between Carthage and Philadelphia is the huge delta built by the Black river in the same water body. The 800-foot level of the upper surface at Fullerville indicates for us the approximate level of the lake at the time the delta was forming.

The shore currents in these bodies of standing water often built bars and spits of sand and gravel, tailing out from the ends of the rock promontories of the shore line. An excellent example is found at Cole, where a sand and gravel spit, over a mile long, runs out to the southwest from the low ridge of hard gneiss just to the north.

There is one hill of moderate size upon the quadrangle, at Kents Corners in the northeastern portion, which appears to be a true drumlin, and entirely of glacial origin. It is of oval shape, with the longer axis north-south, nearly a mile long and a half mile wide, its crest nearly 100 feet higher than the land to the north, and 50 feet higher than that to the south. It stands on granite territory and rock outcrops abound on all sides. But it is composed of bouldery, sandy clay, the boulders very abundant but mostly small, with many large ones lying upon its surface. This hill is noteworthy as being the only one of the type within the quadrangle, and as occurring in a district in which the drift is elsewhere very thin and scanty.

A thin band of moraine, with very little surface relief, stretches across the northern part of the quadrangle, following the limestone belt which runs south of west through East De Kalb. The accumulation is thick enough to hide most of the rock surface along this belt, although occasional rock knobs peep through. The upper surface is flat, and also stony, boulders being plentiful and large. Undoubtedly the surface was smoothed by wave action, and the same action was no doubt responsible for the concentration of boulders at the surface, owing to the washing away of the finer materials in which they were originally embedded.

DRAINAGE

Except for a comparatively narrow strip along the middle-eastern and northeastern portion of the quadrangle the drainage is entirely into the Oswegatchie river and through this into the St Lawrence river at Ogdensburg. The Carter creek-Tanner creek drainage, with its sources in Trout lake, Huckleberry lake and Moon pond, runs off to the northeast and empties into the Grasse river between Pyrites and Canton, on the Canton quadrangle, finally to reach the St Lawrence below the Long Sault rapids.

The Oswegatchie is the most southerly of the four rivers of good size which drain out to the northwest from the Adirondacks and are tributary to the St Lawrence, the other three being the Grasse, Raquette and St Regis. They all rise in the heart of the woods and flow down the northwesterly sloping peneplain. Their present courses are not those which they had preglacially, and are a patchwork of portions of preglacial valleys and other portions which are wholly postglacial and the work of the modern streams. All have a comparatively rapid drop, and exhibit frequent rapids and waterfalls. All flow northwest, across the general trend of the rock structures, which is northeast-southwest. All pursue very erratic courses, with frequent changes in direction. As they near the St Lawrence all swing from northwest to northeast courses, although this change is not so prominent and is more complicated in the case of the Oswegatchie than in that of the other three streams. On the other hand, the Oswegatchie shows a much greater disposition to double back upon itself than the others exhibit.

The minor drainage conforms to the type exhibited everywhere in the New York Precambrian area, what is called the trellised type. The streams flow either parallel to the grain of the country, in valleys eaten out along the belts of weak rock, or else at right angles to this, cross-cutting the rock belts. Such streams as Beaver creek, Carter creek and Tanner creek are predominantly of the first type, flowing long distances along the trend of a single, narrow belt of weak rock; while the lower part of Boland creek, as it flows past Richville into the Oswegatchie, is typical of the other class. Most of the modern drainage, however, is a patchwork of the two types: a stream follows one valley for a distance, then transects a ridge in a narrow valley or gorge into the next adjacent valley, follows that for a space and then shifts across to yet another (plate 1). This is in part due to modifications in their courses produced as a result of glacial action in the region; in other part it is due to the rock structures themselves, since the rocks are folded. The ridges run for a distance and then pitch down below drainage and a weak rock belt wraps around the ridge end. The granite ridges affect the drainage similarly, as in the case of the branch of Indian creek which wraps around the north end of Moss ridge.

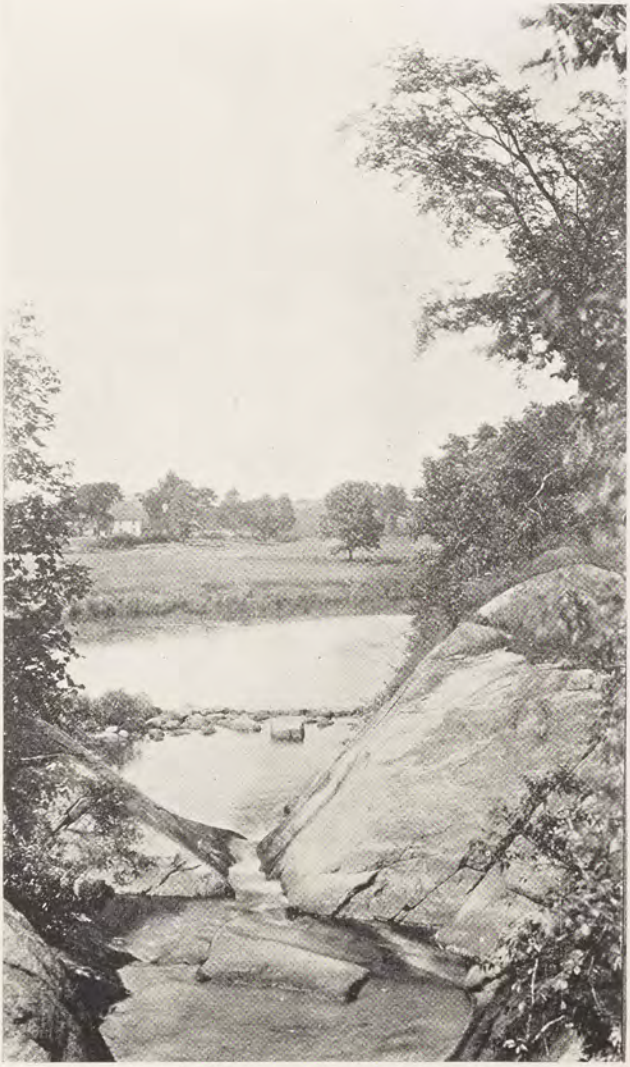
The course of the Oswegatchie across the Gouverneur and Hammond quadrangles furnishes an excellent illustration of all these features. From the river at Gouverneur to the river at Peabody bridge is 3 miles straight across country, and only a trifle more by the wagon road. It is 25 miles by the river between the two points. From Gouverneur the river keeps on in a course slightly south of west to Oxbow, more than half way across the Hammond sheet, where it sweeps round the south end of a series of ridges into a northeasterly course, which closely parallels its previous course for a distance of 4 miles, in two parallel, weak rock valleys. At Wegatchie it is only about 250 yards across the neck of land between the two parallel portions of the river, although it is 5 miles by water from one place to the other. At Little Bow, near the margin of the Gouverneur quadrangle, the river makes a double curve back upon itself, of broad S-shape, occupying short portions of two parallel valleys and swinging round the ends of two ridges, then passing into the valley which, with little variation, it follows across the Gouverneur quadrangle to its north edge and beyond. Other Adirondack streams show a similar doubling back upon their courses, as the Indian river at Evans Mills on the Theresa quadrangle, but no other has this feature in such prominence as the Oswegatchie river.

In its course across the quadrangle the Oswegatchie river shows falls or rapids at Talcville, Hyatt, Emeryville, Hailesboro and Gouverneur, with narrow, rock-cut gorges below the falls. The west branch has a fall at Fullerville. In all these places the stream is in a wholly modern channel. The reaches, in between the falls, may be all developed along portions of the valleys of small, preglacial streams, and in part are certainly so developed, but the river course as a whole is an entirely modern affair. As a contrast to this, the lower portion of the river, from Little Bow to De Kalb, is a long reach in a preglacial valley of moderate size, with no falls whatever. Not a single contour line crosses the stream in this part of its course and the difference in water level between the two points is not over 15 feet; while in the somewhat shorter distance between Edwards and Natural Dam the river drops 260 feet, and 100 feet of that drop is between Hailesboro and Gouverneur.

Lakes

There are a dozen lakes and ponds on the quadrangle, and perhaps an equal number of basins, where shallow lakes formerly existed, but where filling has been completed and the basin is entirely occupied by swamp. Of the still existing ponds, Mud pond, near Sylvia lake in Fowler, is simply a small body of open water enduring in the center of a basin which has otherwise passed over into swamp. Sylvia lake, Trout lake and Mud lake are the largest bodies of water which are wholly or partly within the quadrangle.

Plate 1



Tanner creek emerging from a transecting valley in porphyritic granite into a broad Grenville valley; locality just north of Rock Hollow School.

All these ponds, large and small, filled and unfilled, seem to belong to a single type. They all occupy weak rock belts and were portions of preglacial valleys; all are blocked at one or both ends by a small thickness of glacial deposit, so that their outlets are in modern courses; and the outlets are too small to have any erosive power. Cedar lake, just north of Edwards near the eastern border of the quadrangle, is the only one which may perhaps occupy a real rock basin, but it connects directly with swampy territory, both to the south and to the east, and would apparently have a clear path to the Oswegatchie, between Edwards and Talcville, except for slight glacial filling in between.

All the villages in the region obtain their water supply from the Oswegatchie, along which they lie. The river water, however, is by no means as unpolluted as could be desired, and these lakes might be utilized as a source of a much purer supply.

CULTURE

Roughly speaking the surface of the Gouverneur quadrangle is about 50 per cent cleared and utilized for agricultural purposes, while the other half consists of wild land. The belts of unmixed limestone are completely cleared, the impure limestones and schists largely so, and some of the broader granite areas, such as the one in Gouverneur and the Maple ridge belt in De Kalb, make excellent farming territory. In these latter there are frequent bare knobs of granite which stand above the general level, but except for these the surface is comparatively even and, with a sufficiently thick morainic covering that is not very stony, furnishes an excellent soil. The dairy industry is the chief one, and hay and oats are the principal crops.

In contrast, the relatively elevated territory whose surface rocks are amphibolites, garnet-gneisses and granites, is chiefly wilderness. The timber was cut away long ago; fires followed, and now thickets of bushes, briers and small trees cover the land. The most extensive areas of the sort are the garnet-gneiss territory in Edwards, in the southeastern part of the quadrangle, and the granite, garnet gneiss, amphibolite tangle in Hermon, Edwards and Fowler, lying chiefly north of the river, but cut through by it between Hyatt and Hailesboro. There are many smaller patches of similar country elsewhere, but these are closely surrounded by better land and are partially cleared and somewhat used for pasture. The densely wooded swamps in the filled lake basins also belong in the wilderness category.

GENERAL GEOLOGY

The exposed rocks of the Gouverneur quadrangle are chiefly of Precambrian age. The only exceptions to this are the frequent but small patches of Potsdam sandstone, found here and there, resting on the unevenly worn surface of the crystalline rocks, and the glacial deposits which form the immediate surface over much of the district. About fifty separate patches of Potsdam sandstone are shown on the map, and there are many others which are too tiny to be mapped upon this scale. They represent the residuum of what was formerly a great sheet of sandstone which overspread the entire Precambrian surface, with the possible exception of a few of the higher knobs.

The Precambrian rocks of the quadrangle comprise both sedimentary and igneous rocks, as is invariably the case in northern New York. But the igneous rocks greatly exceed the sediments in quantity in most of the quadrangles, and the Gouverneur region is quite exceptional in the large area of sediments shown. All these sediments are classed in one ancient and thick group of rocks, the Grenville series. No trace of any other sedimentary series of Precambrian age has ever been discovered in northern New York.

The Grenville rocks are also the oldest rocks exposed. Being a group of sediments they must have been deposited on something, but no certain trace of this old floor of deposit has ever been discovered in New York. While it is always possible that some such find may be made, it seems today most probable that this old floor was entirely engulfed in the great floods of molten igneous rock which attacked it from beneath.

The igneous rocks of the region are all of Precambrian age and all younger than the Grenville, as they all cut the sediments intrusively, notwithstanding the fact that the sediments rest on them. They are believed by the writer to belong to three separate groups of widely different age: an early group consisting chiefly of gneissoid amphibolites and granites, the former older than the latter; a considerably later group comprising anorthosite, syenite, granite and gabbro; and a still later group consisting chiefly of diabase. All three groups are believed to be represented in the Gouverneur quadrangle.

The Grenville rocks are found to be quite sharply and closely folded, in a series of isoclinal folds, which often show a sharp pitch. The granite-gneisses of the early group occur in bosses or bathyliths of oval shape. The porphyritic granites of the later group appear here as sills, a rather exceptional mode of occurrence for these intrusives in northern New York. The Grenville rocks seem to have been already metamorphosed and folded to about their present extent, before the intrusion of these sills took place; and the sills themselves seem to be up-shoots from a large mass of syenite and porphyritic granite below ground, whose upper surface has not yet been reached by erosion.

GRENVILLE SERIES

Crystalline limestone and garnet-gneiss are the most important members of the Grenville series within the Gouverneur quadrangle. The great belt of limestone which extends across the map from southwest to northeast is the local exhibit of what is the longest and thickest belt of Grenville limestone in northern New York, as was long ago pointed out by Smyth. It by no means consists exclusively of pure limestone; there is a great thickness of impure, quartzose limestone, a rock described by Martin as "quartz-mesh" limestone as it occurs on the Canton quadrangle.[1]

As pointed out by him this rock varies through imperceptible gradations into limestone, on the one hand, and into quartzite, on the other. There are also bands of hard gneisses of various sorts interbedded with the limestone. But even after these deductions there remains an enormous amount of exceedingly pure, massive limestone.

The garnet-gneisses are a common member of the Grenville series everywhere in northern New York. In many cases they are interbanded with other gneisses with the formation of a complex whose members are too thin to be mapped separately. Nowhere else in the region have we seen this rock in such purity and with such great areal extent as it possesses on the Gouverneur quadrangle. It is not only readily mapped separately but it covers many square miles of territory.

The bands of hard gneiss interbedded with the limestones are chiefly made up of hard, flinty, fine-grained rocks, of reddish, grayish or greenish hue, which invariably carry tourmaline as a constituent, sometimes black, at others brown or white. Such rocks are quite a feature of this immediate district, but are rare elsewhere, so far as our experience goes.

Many thin bands of pyrite (rusty) gneiss, of mica-gneiss (both coarse and fine grained), and of quartzite occur within the quad-

[1] N. Y. State Mus. Bul. 185, p. 22–23.

rangle, but mostly too thin and too interbanded to justify separate mapping. In comparison with other parts of the region, the lack of thick formations of these rocks, especially of the quartzites, is noteworthy.

Structure

The strongly-folded condition of the rocks makes it difficult to arrive at any precise estimate of the stratigraphy or the thickness of the Grenville series here. The garnet-gneiss is the oldest member shown within the quadrangle, and appears in outcrop along the axes of anticlines; it is directly overlain by the thick limestone member, which is pinched into synclines between the garnet-gneiss belts. By the same token, it would appear that the belts of hard schist within the limestone in the northwestern half of the quadrangle belong just above it stratigraphically and occupy synclinal axes within the folded limestone. In this same portion of the quadrangle the garnet-gneiss fails to reach daylight along the anticlinal axes, suggesting that the folds form part of the western limb of an anticlinorium, or the eastern limb of a synclinorium, so that higher and higher beds appear in passing northwest; and that probably the schists and quartzites of the Alexandria Bay quadrangle belong yet higher in the section than any of the rocks shown on Gouverneur. Between the two lies the Hammond quadrangle, and this has not yet been mapped in detail. In the abundance of Grenville and the relatively small amount of intrusives it much resembles the Gouverneur quadrangle. Its Grenville consists of successive belts of limestone and of schists, and its careful mapping should greatly aid in the elucidation of the general structure.

In the Alexandria Bay section evidence was presented suggesting that the thick limestone of the eastern portion of the Theresa and Alexandria Bay sheets, was folded into a syncline, with a series of schists beneath and another of schist and thick quartzite above it.[1] The schists beneath do not at all suggest the garnet-gneiss which underlies the big limestone of Gouverneur. The garnet-gneiss is an injection-gneiss, and it is perhaps possible that the schists of Alexandria Bay would become converted into garnet-gneiss by means of "lit-par-lit" granite injection. But the Alexandria rocks are of the "green schist" variety, are much cut by granite, and yet bear no resemblance to the garnet-gneiss. They seem to have been originally rocks of higher lime content than the garnet-gneisses could have pos-

[1] N. Y. State Mus. Bul. 145, p. 109–11.

sibly been and appear to us to represent an entirely different member of the Grenville. If so, the limestone which overlies them can not be the same formation as the great limestone of the Gouverneur quadrangle, but must be a higher member of the series, and an unknown thickness of schist lies between. Whether the hard schists which overlie the limestone on Gouverneur represent the basal portion of the schist formation which underlies the limestone on the Alexandria sheet, or whether other members intervene on the Hammond sheet, is a question, the answer to which must await the detailed mapping of the latter. Lithologically they are quite similar, calcareous pyroxene gneisses being a prominent constituent in each case.

In so far as the Gouverneur quadrangle alone is concerned, attempts to estimate the thickness of Grenville shown are comparatively futile. The folds are complex; a limestone syncline or a garnet-gneiss anticline can not be treated as simple folds in efforts to measure thickness. On the contrary, the field facts demonstrate that the limbs of the large folds are themselves contorted into minor flexures. If the interpretation of the stratigraphy of the region which has just been set forth comes anywhere near the truth, the Grenville section of the district is something as follows:

	Section	*Thickness in feet*
5	Quartzite and schist	3000′
4	Limestone	4000′
3	Hard schists, largely green schists	4000′
2	Limestone	5000′
1	Garnet-gneisses	4000′
		20,000′

Because of the complex folding these thicknesses are mere estimates. No. 3 is the most uncertain member, and study of the Hammond sheet may greatly expand it, and may show an additional member or members between Nos. 2 and 4. But all thicknesses are subject to much correction, that of the limestones especially so because of their massive character and of their plasticity under compression.

If, because of the general northeast strike and northwest dip, the structure be regarded as that of an unbroken monocline, then this reasonably unbroken section, extending across the full width of three quadrangles, would have a prodigious, an unbelievable thickness.

Grenville limestone

Two belts of crystalline limestone extend across the Gouverneur sheet, one of which, the great belt already referred to, occupies the entire northwest half of the quadrangle, except for certain infolded bands of schist of no great thickness, and for various intrusive masses of granite and amphibolite; the other the band which crosses the southeast corner of the sheet, from Sylvia lake to Edwards. In each case the limestone rests on garnet-gneiss, suggesting that the stratigraphy is the same and that we are dealing with two synclinal troughs carrying the same limestone member. The Edwards band is much narrower than the other and consists chiefly of impure, quartzose limestone. Much impure limestone also occurs within the other belt, especially in its basal portion. But nothing has been noted in it which can be definitely correlated with the talcose member of the Edwards belt; and the sphalerite deposits are also confined to it, as far as is known. These differences might be thought to suggest that we are dealing with two distinct limestone members; but the similar stratigraphy, together with the known folded structure, leads to the belief that the same limestone is concerned; that the Edwards band is not so deeply down-folded as the other, because of which only the basal portion of the member is present there, instead of the full thickness as is the case in the other belt; and that the talc and zinc deposits of the Edwards belt were formed because of local conditions which failed to obtain in the great belt.

The limestone is of two general types, the comparatively pure and the very impure, although there are, of course, many intermediate types. Each type shows much variation.

The larger part of the pure limestone is of white color and of medium-coarse grain; but there is much and often rapid variation in the latter respect, the rock running from very fine to very coarse grain. Tiny flakes of brown mica (phlogopite) and of graphite and occasional small crystals of pyrite are invariably present but in small quantity, much of the rock running from 95 per cent to 99 per cent calcite. A faint bluish tinge is perhaps a more common color than the dead white, although there is much of each sort. There is also quite an amount of rock of prominent bluish gray color, although there is much less of it than of the light-colored rock; and sometimes the two colors are interbanded, the bands sometimes narrow, at others wide (plate 2). But by no means is all the banded limestone of the district of this type; more commonly it is due to alternating bands of pure and of very impure limestone.

Plate 2

Color-banded Gouverneur limestone, by the state road near Pine Hill School, Macomb township, Hammond quadrangle; a better exhibition of such limestone than was anywhere seen on the Gouverneur quadrangle. Strike northeast and dip northwest. View looks northeast.

Plate 3

Gouverneur limestone in Corrigan & McKinney pit north of Gouverneur looking west along north wall of pit to the northwest corner. Solid, massive, white, pure limestone.

Neither is there any large quantity of banded limestone of any type within the quadrangle limits. The great bulk of the rock is of very light color and so massive that the bedding is made out with great difficulty if at all. The rock is cut by more or less frequent joints, often quite irregularly, and at the surface these are frequently widened by solution. In plate 3 is shown the exposure of limestone at the Corrigan and McKinney pit, near the railway 2 miles north of Gouverneur. On the left of the view the limestone is exceedingly solid, massive and pure, while midway is a zone with abundant jointing.

No great amount of dolomite has been observed within the quadrangle limits, outside of the Edwards-Sylvia lake belt. We have seen nothing to correspond with the brown-colored dolomite formation which Miller and Knight describe underlying limestone in the Grenville, in several districts in Ontario.[1] In fact we have seen very little brown limestone of any sort in northern New York, whether magesian or not. The great mass of our pure limestone is white, rather than blue, unlike that in Ontario, although much of ours is faintly bluish. There is, however, some dolomite present on the Gouverneur quadrangle, but in no great quantity and within the general mass of the rock, rather than at its base. Within the belt of limestone at Rock Island School, 4 miles north of Gouverneur, and thence southwest toward Peabody bridge, is a considerable mass of dolomite. To the eye it presents little to distinguish it from the limestone, as it is a coarsely-crystalline, white marble, and, as such, it is excellently shown in the quarry one-half mile southwest of Rock Island School. But often, as at the school itself, it contains much tremolite, both as single-bladed crystals shot through the rock, and in great, spherically-aggregated masses of crystals. The band has no great width and is bordered by ordinary limestone on both sides.

It is not to be understood that the tremolitic phases are confined to dolomite. Tremolite is quite common in the limestone also, in so many localities that it is not worth while to give a list. Sometime pyroxenes of light color in long crystals appear. An accessible locality of this sort occurs just out of Gouverneur on the Hailesboro road a short distance south of the cemetery. Here a nose of one of the main quarry ridges of limestone comes to the roadside and has been blasted. The rock is somewhat impure, of bluish color, and contains many stoutish, but nevertheless long prismatic, crystals,

[1] Bur. of Mines, Ont. v. 22, pt 2.

up to 3 inches in width and with length about 4 times the breadth, whose crystal form seems to prove the mineral to have been originally pyroxene. It is now completely altered to a nearly black material of uncertain nature.

Tourmaline Locality.

Certain silicified bands, or spots, are also found within the pure limestones. A notable instance, which may serve as a type, is found at the well-known brown tourmaline locality. This is situated on the Reese farm, southwest of Richville and 2 miles from the town on the Richville-Rock Island School road, and is the locality from which museums have been furnished with the excellent specimens of this mineral, usually labeled as from Gouverneur. This is correct if it is understood that the township is meant and not the village. Some ten pits have been opened on the "pay streak" which is spottily developed along a comparatively narrow band in the limestone for a distance of some 300 yards. Great masses of coarsely crystallized lime-magnesium silicates, tremolite and diopside, are developed in the limestone, and tourmaline crystals are thickly sprinkled through these, notably the tremolite, and through the accompanying coarse calcite. Apatite, phlogopite mica, titanite and pyrite are also associated but in comparatively small amount. The band is wholly inclosed in pure limestone, no nearby igneous rock showing. The small knobs of white granite near Richville are 2 miles distant; the granite-gneiss margin lies one-quarter of a mile away to the south. Yet the mineral association at the occurrence is so typically of the sort which would be produced by the attack upon limestone of hot, siliceous solutions given off from some nearby granite mass, solutions containing mineralizers in quantity though lacking iron, that the occurrence is most reasonably explained on the assumption that granite occurs in place not far below ground, and that solutions given off from it worked upward through the limestone, attacking it and giving rise to the silicates.

Impure Limestone

The impure limestones of the district are of two types, those which have arisen from the metamorphism of portions of the limestone that were originally impure, and those made impure by contact action of igneous rocks. The first type is widespread in the quadrangle; the second is local and in but small bulk.

The lower portion of the great limestone of the quadrangle seems originally to have been quite siliceous. It has metamorphosed to a calcite-quartz mixture, ranging all the way from pure limestone to pure quartzite, although the greater part of the rock contains more, usually much more, calcite than quartz. Sometimes the two minerals are quite intimately mixed; but the quartz tends usually to coarseness of crystallization, with the formation of knots and lumps of quartz within the limestone, or to the construction of a coarse, quartzose mesh with calcite-filled interstices. On weathering, the less soluble quartz stands out in relief on the rock surface. At other times the quartz forms thin bands in the limestone which, in mashed portions of the rock, become disrupted into angular fragments which are squeezed apart and separated from one another by movement in the more plastic calcite.

With increase in the amount of quartz, these impure limestones grade toward and pass into thin-bedded quartzites; but there is relatively little of such rock in the quadrangle, although there is much of the quartzose limestone. The belts mapped as impure limestone consist chiefly of this rock. In the Edwards belt, especially around Sylvia lake and thence northeast, is a great thickness of interbanded quartzite and limestone, both thick and thin bands of each in rapid alternation which in many places have not been greatly pressure-disrupted, that seems to represent a metamorphosed member originally made up of rapidly alternating limestone and sandstone beds. The same belt in the vicinity of Fowler shows vastly more disturbance and disruption.

The talc deposits are in this general series, usually in the near vicinity of amphibolite masses. As Smyth showed long ago, the original rock was a tremolite schist, consisting of tremolite with a varying amount of quartz, the tremolite largely altered to talc.[1]

An unusual variety of impure limestone occurs in this same belt, usually in close association with the zinc deposits. The limestone is full of lumps and masses of green serpentine, of all dimensions and often of quite irregular shape. In a small proportion of these, particularly of the smaller ones, the mass consists entirely of serpentine, but the larger number have a peripheral serpentine band and a central nucleus of gray, impure talc.[2] On weathering these nodules whiten and, because they are less soluble than the limestone, project in relief from the weathered surface (plate 4). The inclosing limestone is also of the ophicalcite variety, a dolomite-serpentine

[1] School of Mines, Quarterly, v. 4, p. 333-41.

[2] See plate. The serpentine rims of the nodules in the figure are somewhat thinner than the average, and the talc centers correspondingly larger.

aggregate of varying coarseness. Such ophicalcites are quite common in the Grenville of northern New York, and have resulted from the alteration of pyroxene to serpentine in original dolomite-pyroxene limestones, such as are next described. The talc centers of the nodules form a very unusual feature.

Between Gouverneur and Hailesboro the pure limestones show, locally, angular included fragments of hard, black amphibolite, which represent the disrupted fragments of either a narrow bed of amphibolite, originally interbanded with the limestone, or of a narrow dike of the gabbro-amphibolite.

White or green pyroxene and scapolite are two other minerals which are of quite common occurrence in the limestones. Even in the very pure rock, which seems to consist entirely of calcite, close inspection will show one or both of these minerals to be present. Thus in the Gouverneur marble belt, south of the village, where the most active quarrying is done, the white limestone contains white pyroxene in many localities, and the blue bands contain often much green pyroxene in small, roundish crystals, as well as some scapolite. From such rocks as these are found all gradations to impure limestones which contain 50 per cent or over of pyroxene and scapolite, and from such onward into rocks in which the calcite practically disappears, and the abundant calcium of the rock is all in combination with silica. Such rocks, however, are not particularly abundant in the quadrangle, but are of local occurrence only, and in comparatively small amount. They are most common in De Kalb in the extreme northeastern portion of the quadrangle where there is much impure limestone.

Grenville Schists

There are four belts of schist which run across the quadrangle, and two others consisting of schist involved with amphibolite and granite. Four belts of clean schists are found in the northwestern half of the quadrangle, infolded with the limestone and, because of local sharp pitch, pinching out within it. Two of the belts are in the extreme northwest, in the vicinity of the branches of Beaver creek. They pinch out in the limestone to the southwest and are comparatively short. They coalesce into one belt at the north edge of the sheet and pass as such on to the Ogdensburg quadrangle. Four miles to the northeast, on that quadrangle, limestone swings round the end of the belt and cuts it out. These two belts are conveniently described together and will be called belt no 1.

Belt no. 2 comes on the sheet from the Hammond quadrangle 2 miles north of Natural Dam, very narrow at first, and remaining so for 4 miles. Below Rock Island bridge it rapidly expands to a width of well over a mile. For all this distance the Oswegatchie closely follows it. Below the Richville bridge a great boss of gabbro-amphibolite cuts out the western half, but the remainder has a breadth of a full mile. Three miles below Richville it becomes infolded with the great limestone which splits it into two unequal arms; and 3 miles farther away both belts pinch out, and limestone swings around their ends.

Belt no. 3 appears in the limestone at the west edge of the village of Gouverneur as a narrow belt, and runs north to the edge of the granite-gneiss which cuts it out. South of the river its presence is uncertain, the country in that direction being low and covered with drift. What seems to be the same belt reappears on the east margin of the granite-gneiss, and runs steadily to Richville depot as a narrow belt. Beyond that it broadens considerably and continues across the quadrangle and on to the Russell quadrangle beyond. At this end it becomes involved with amphibolite to a large extent. The belt is noteworthy in that it contains a very persistent band of quite pyritiferous rusty gneiss along its east margin.

Belt no. 4 runs southwest from the zinc mine near Edwards, passing through Talcville and on to the edge of the stock of amphibolite where, at the west branch of the Oswegatchie, it is cut out. It is in contrast with the other belts in being much more involved with dikes and sheets of amphibolite than they are. At its northern end, where it pinches out in limestones, it consists largely of granite and amphibolite. A mass of very red granite cuts it at Talcville. Elsewhere the schists prevail, but always with intermingling of the intrusives.

There is a varied assemblage of rocks in these schist belts, both in appearance and in composition, although all are referable to comparatively few types. The range is from very siliceous rocks—quartzites—down to those with no free quartz and low silica percentage. The bulk of the formation, in most cases, consists of rather fine-grained, hard, resistant rocks, often almost flinty in appearance and consistency, hence the belts stand somewhat in relief above the adjacent limestone country, and show frequent sharp, and often rugged, knobs.

Quartzite occurs in all the belts, and particularly so in no. 1. It occurs in both thick and thin beds, in part finely granular and in part coarsely crystalline. But the rock is always interbedded with the schists so that there is nothing within the quadrangle at all comparable to the thick quartzite formation of the Alexandria Bay and Grindstone quadrangles of the Thousand Island region. There is a particularly large amount of quartzite in the broad schist belt to the west of Osborn lake, to the north of the amphibolite stock. This is an excellent locality at which to observe the relations between schist and amphibolite, the linear ridges of schist and quartzite striking squarely against the north face of the amphibolite, and being as squarely cut off by it. The quartzite in this belt is interbedded with impure limestone and with hard, fine-grained mica-gneiss of general dark gray color. In the comparative abundance of quartzite and the scarcity of the green, pyroxene gneisses which abound in belts nos. 2 and 3, this belt no. 1 contrasts rather strongly. The subsidiary ridge in this belt, the schist ridge which is cut out at the north by the granite at Osborn lake, consists chiefly of hard, mica-gneiss.

The narrow southern end of belt no. 2 also consists largely of hard mica-gneiss with interbedded thin quartzites, with an occasional thin limestone band, quite like the previous except that there is less quartzite. There are also occasional bands of the impure, hematitic quartzites, which weather readily, and which are common rocks in the Grenville in many localities. With the broadening of the belt to the northeast, while still consisting largely of mica-gneiss, beds of white, red or green, fine-grained, hard pyroxenic gneisses come in also in considerable bulk. There are also beds of very black, very dense, very fine-grained mica-gneisses, which resemble amphibolite, but prove to hold no hornblende. They are probably regular members of the sedimentary series.

In belt no. 3, especially in the northeast portion of the quadrangle, where it is broad, there is a great development of these green and red pyroxene gneisses, although beds of quartzite, mica-gneiss and impure limestone are always present.

In all these belts one surprising character of all the gneisses is the universal presence of tourmaline as a constituent, often in quantity. Tourmaline in pegmatites and in contact zones is also present, but is not here referred to, the tourmaline being disseminated through the gneiss as a regular constituent. It is sometimes black, sometimes brown, sometimes dark green, sometimes white (colorless in thin section). The crystals are usually very tiny and in general not to be made out except in thin section under the microscope. Out of forty thin sections of various types of these gneisses, twenty-five contain tourmaline: in ten it is black, in eight brown, in four green and in three it is white. In the green schists in Alexandria, to which structural reference has already been made, and which are very similar rocks, if not the same identical formation as these schists of Gouverneur, tourmaline is a frequent minor constituent; but it is present there in nothing like the force that it is here. In the rock cliff on the south side of the river at Rock Island bridge is a great band of very hard, fine-grained, gray-black rock which is a quartz-feldspar-tourmaline rock, in the proportions of 10 per cent quartz, 40 per cent microcline and 50 per cent tourmaline. This is, of course, an exceptional rock, but in several other cases the tourmaline constituted from 5 to 15 per cent of the rock. It is present in much greater quantity than in the Alexandria rocks, and its abundance rather reinforces the conclusion arrived at in accounting for the mineralization of the limestone at the Richville brown tourmaline locality already described, the probable presence of a large mass of porphyritic granite below ground, from which mineralizing solutions have worked their way upward, and prominently affected these schists.

A ridge of hard, dense, red gneiss, of alternating very fine-grained broad bands and narrow, coarser-grained ones, crosses the state road 2 miles north of Richville. The rock is chiefly a feldspar-brown tourmaline combination. The fine-grained bands consist of an intimate, half and half mixture of brown tourmaline and feldspar (probably albite) with frequent tiny rutiles and an occasional pyrite. The coarser bands consist chiefly of albite but hold occasional tourmalines. The rock as a whole contains about 35 per cent of tourmaline.

The general run of these pyroxene gneisses are of green color and contain from 25 to 35 per cent of pyroxene of varying shades of green. Titanite is a very abundant accessory mineral in nearly all of them. Sometimes epidote and actinolite are present also, but more usually they are not. The very pyroxenic rocks contain little or no quartz, while those with less pyroxene carry from 5 to 15 per cent of that mineral. The feldspar varies much in the different varieties; it is usually plagioclase—albite to andesine—but often much microcline is present. Scapolite is a very common constituent.

The red rocks are much poorer in pyroxene than the green and consist largely of feldspar and scapolite, with tourmaline and rutile, and in general with a high degree of alteration in such pyroxenic constituents as are present. The interbedded quartzites and mica-gneisses also contain frequent tourmaline. On the state road, a half mile north of the red, tourmaline gneiss just described, is a cut in rusty gneiss full of pyrite. Otherwise the rock is firm, white and fine-grained, and consists of a feldspar-quartz mosaic with a little mica, frequent small rutiles, and quite abundant white tourmaline.

The mica-gneisses are, in general, firm, fine-grained rocks, quite resistant to weathering, in part with the mineral constituents pretty evenly distributed, in other part banded rocks, dark-colored micaceous bands alternating with white ones nearly free from mica. They are quartz-feldspar-mica rocks, the mica chiefly phlogopite, the feldspar microcline or microcline and acid plagioclase in varying proportions. The feldspar may greatly exceed quartz or the reverse may be true, the relative quantities of the two varying much from place to place. Titanite, zircon and apatite are usual accessories, while graphite often, rutile sometimes, and tourmaline in many instances occur. With these usual gneisses are frequently very micaceous beds which weather with great rapidity, and hence seldom show well in outcrop except in rock cuts of recent make.

There are other very micaceous beds which are much more resistant and much resemble amphibolites, and such beds are sometimes present in bulk. In part they rudely resemble "augen gneisses" owing to the development of small rounded areas which are much poorer in mica and hence of much lighter color. These are biotite, rather than phlogopite rocks, and the mica constitutes from 25 to 50 per cent of the rock. Tourmaline, usually of dark green color, is often present in abundance, while apatite and pyrite are the most prominent accessories. Quartz does not in general exceed 10 per cent of the rock, and the feldspars are acid plagioclase and microcline.

All these mica-gneisses are quite certainly metamorphosed shales, while the pyroxene gneisses are derived from calcareous shales and very impure limestones.

These gneisses show such manifold variety that it is an almost impossible matter to give a good general description of them. In the Edwards belt they are much cut by dikes of aplitic granite and by amphibolite, but otherwise are of the type just described. In all the belts much of the gneiss is strongly altered. Certain of the minerals in many of the slides show a mere jumble of alteration products, so that the original mineral can not be definitely made out, and this is particularly the case in the Edwards belt. Moreover, the alteration is not of the type produced by weathering, but of the pneumatolitic type, and thus reinforces the suggestion already made that the schists have been strongly attacked locally by solutions arising from granites below ground.

Rusty Gneisses

The rusty gneisses are those members of the general gneiss series, either quartzites or quartz-mica-gneisses, in which pyrite is so largely developed that the rock weathers and crumbles readily and takes on a rusty appearance in outcrop. Such rocks occur within the quadrangle in three different ways. They are found interbanded with the hard gneisses, interbanded with the limestones, or as marginal bands separating limestones from adjacent igneous rocks. In the latter case their situation suggests that they may be contact rocks, but such a conclusion is of course forbidden by the character of the rock itself, and by the fact that identical rocks occur within the Grenville away from the intrusives. It is, however, true that a selvage of rusty gneiss between granite and limestone is such a common feature of the geology of the quadrangle as to strongly reinforce Smyth's suggestion that much of the concentration of pyrite in the rusty gneisses of the region is due to the action of circulating solutions which were in part at least of magmatic origin.[1]

The general rusty gneiss is a siliceous quartz-feldspar rock with but little mica, and with much pyrite. At the surface the pyrite rapidly weathers and disappears and the rest of the rock either breaks down or becomes porous and cavernous and stained by iron oxide. There are several belts of the rock within the quadrangle. They are:

1 A narrow belt, about 5 miles long, runs from west of Sylvia lake to Fowler, lying between limestone on the east, and amphibolite and granite on the west. At Fowler it is cut out by amphibolite but what seems to be the same band reappears to the west of Talcville for a short distance and then is cut off by granite.

2 The narrow belt of hard gneiss at the western edge of Gouverneur village consists largely of rusty gneiss. Cut out by granite it reappears again on its east edge and the rusty gneiss forms the easterly margin of the band of hard gneiss there mapped, becomes very prominent at the Cole mine, and continues thence to the northeast all the way to the Stella mine at Hermon on the next quadrangle, where it becomes involved with amphibolite. It is thus the longest continuous band within the quadrangle.

3 There is a considerable belt of rusty gneiss in the extreme northwest corner of the quadrangle. On the Ogdensburg sheet it quickly disappears under the Paleozoics. The southwest, on the Hammond sheet, its extent has not yet been mapped.

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[1] N. Y. State Mus. Bul. 158, p. 170–82.

4 A band is associated with the amphibolite at Halls Corners, where it pinches out in limestone at the north end of a pitching syncline. Each limb of the syncline has a long extent on the Hammond sheet, as recently shown by Buddington, the two limbs constituting his Laidlaw and Keene-Antwerp belts.[1]

5 The great knob of sharply pitching gneiss just northeast of Pleasant Valley School, southeast of Talcville, has a strong band of rusty gneiss.

In addition to these chief bands rusty gneiss outcrops in a host of other localities within the quadrangle, as inclusions in the igneous rocks, as narrow selvages between limestone and granite, or in belts too narrow or too short to warrant attempts at separate mapping.

Garnet-Gneisses

In his report on the Precambrian Rocks of the Canton Quadrangle, Martin gives a very full discussion of the garnet-gneisses encountered on that area.[2] He discusses these rocks under three types:

First that which forms the greater part of the large S-shaped fold found in the southeast corner of the quadrangle; second, the long, narrow bands of garnetiferous rock which are characteristically associated with the periphery of areas of granite-gneiss; third, all other occurrences, found independently of the first two types and interbedded with typical Grenville sediments.

On the Gouverneur quadrangle these rocks have a much greater areal distribution even than on Canton, and it will facilitate our discussion of them to follow his subdivisions of type. It remains to be stated that the two great areas of garnet-gneiss, the one to the south and the other to the north of Edwards, and in addition the narrower belt in the center of the quadrangle, running from the sheet margin south of Gouverneur up to Moss ridge, belong distinctively to his first type; that representatives of the second type are numerous, a notable instance being in the case of the narrow but very long inclusion of garnet-gneiss and limestone within the granite along Tanner creek in the east portion of the quadrangle; and that representatives of the third type, thin bands of garnet-gneiss interbedded with other Grenville sediments, are practically nonexistent on the Gouverneur quadrangle.

These garnet-gneisses are quite characteristic members of the Grenville series in northern New York, particularly in the southern

[1] N. Y. State Defense Council Bul. 1, p. 3.
[2] N. Y. State Museum Bul. 185, p. 24–40.

and western parts of the region. The writer has not met them in anything like the same prominence on the east and north; but those are the districts where the intrusives greatly predominate and there is much less Grenville than on the south and west. Our impression is that garnet-gneiss is much less conspicuous as a Grenville member in the northeast half of the region; but we are not sufficiently sure of the correctness of this position to wish to emphasize it too strongly.

The extensive masses of garnet-gneiss of the first type will be shown to be, structurally, the lowest member of the Grenville series represented within the quadrangle. They rest either upon igneous rock or on sediments which are nowhere exposed at the surface. Nowhere are they pure sediments but on the contrary are quite typical injection gneisses, being everywhere shot through with *lit-par-lit* granite and pegmatite bands (plate 4). From these bands cross-cutting dikes radiate, and from them also material has worked its way into the remainder of the rock, which is everywhere more or less granitized, though the degree of this varies much from place to place. The general rock has a dark gray color, while the granitic bands are usually white, more rarely red, so that the rock as a whole is usually strongly color-banded. The light-colored granitic bands vary greatly in abundance, rising to as high as 50 per cent of the rock, and falling to 5 per cent or less. Often their boundaries are subparallel for considerable distances so that the banding is very regular; equally often it is quite irregular. Certain of the granite and pegmatite films show very sharp, even boundaries against the adjacent gneiss; others as constantly break out into and impregnate the gneiss with granitic material.

The typical garnet-gneiss consists of quartz, feldspar and mica. The quartz content varies from 10 to 33 per cent, with an average of from 20 to 25 per cent. The feldspar is chiefly alkali feldspar, orthoclase or microperthite with some microcline, but there is always some and often much plagioclase, usually oligoclase, in addition. The usual mica is biotite, but sometimes phlogopite replaces it. The granitized and nongranitized bands have the same mineralogic make-up, and their chief composition difference consists in the abundance or scarcity of the mica, which is abundant in the gneiss and scant in the granite. Garnet, titanite, zircon and pyrite are the universal accessories. The garnets occur throughout most of the rock, although in very varying quantity. Although they have a considerable range in size, they are for the most part small, and of a pinkish shade instead of deep red. When large they are often skeleton crystals, full of inclusions, but this is not prominently the case with the usual small ones. They seem in all cases to have been the last mineral to form and likely to have resulted from the action of the granitic on the shaly material, notwithstanding the fact that they occur scattered through the whole rock, both the granitic and the gneissose portions. As a whole, however, they are much more abundant in the latter than in the former.

Besides the ordinary variety of garnet-gneiss, injected with white granite and pegmatite, there is also a nongarnetiferous variety, of the same mineralogy as the other except for the lack of garnet. Much of the injecting granite which ribbons this rock is red instead of white, and as a whole it does not carry so much granite as does the other. It occurs in part in small thickness interbanded with the garnetiferous variety, and in part in large thickness with less intermixture of the other. It is found in large thickness in the extreme southeast portion of the quadrangle east of Bonner lake. Excellent localities showing the intermixture of the two varieties may be seen along the Trout lake road, just west of the lake and also farther north.

These garnet-gneisses are widespread in northern New York. They are abundant all along the south margin of the Adirondacks and, in reporting upon them in the Saratoga region the writer argued that they were injection gneisses, the white bands being of igneous origin.[1] Martin holds the same view for these rocks on the Canton quadrangle. The original rock must have been a shale and only slightly calcareous, since the present rock holds very little lime. The shale has been metamorphosed to a mica-gneiss, and thoroughly penetrated and impregnated by injected granitic and pegmatitic material.

The garnet-gneisses of the second type are such as occur as selvages between limestone and granite, in imitation of contact zones. The great inclusion, 5 miles in length, within the granite which lies along Tanner creek in the east-central portion of the quadrangle and consists of central limestone with a continuous border of garnet-gneiss on each side, is the most conspicuous example found, although others are frequent. The long belt of the gneiss which runs diagonally across the quadrangle from southwest to northeast and wraps round the south end of Moss ridge in complicated fashion, and which lies between granite on the east and limestone on the west, is another example, but not so striking as that of Tanner

[1] N. Y. State Mus. Bul. 169, p. 18.

Plate 4

Garnet injection gneiss from exposure by the Trout Lake road 1 mile south of Trout Lake School, the light colored bands being of white granite and the darker ones of mica-gneiss. Garnets are too small to show plainly and are not abundant. The first band of mica-gneiss on the left is considerably soaked by granite, and the granite band on the right contains much gneissic material.

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creek. The position of such belts definitely suggests their contact nature, but the writer is in entire agreement with Martin who holds that they can not be regarded as contact rocks. The rock is precisely like that in the belts of the first type, where there is nothing to suggest a contact origin; the boundary of the garnet-gneiss against the limestone is always sharp, with no sign of the gradation of one rock type into the other which would normally be expected were one a contact form of the other; neither is the mineralogy of the garnet-gneiss that of a limestone contact rock, aside from the garnets. The gneiss is practically free from lime. As a result of microscopic analysis, it may be confidently stated that it contains probably less than 2 per cent of calcium on the average; and it is difficult to conceive of any process whereby a limestone could be converted into such a rock. In the granite are many inclusions of limestone, both large and small, which show no sign of garnet-gneiss borders; there are also many inclusions of garnet-gneiss with no sign of limestone. We are therefore driven to the conclusion that the garnet-gneisses of the second type owe their position to purely structural causes, that the gneiss is an integral member of the sedimentary series of Grenville age and underlies the great limestone, that the Tanner creek inclusion is a syncline pinched in the granite, with the lower portion of the limestone formation folded down into the upper beds of the gneiss, and that the long garnet-gneiss belt diagonally across the quadrangle center lies in the east limb of a syncline with the gneiss in normal position underneath the limestone.

The question naturally arises why these particular gneisses are so thoroughly penetrated and impregnated by granite, in contrast with the other Grenville sediments. It is the common experience in the region that all garnet-gneiss areas, and most of those of amphibolite, are full of veins and sheets of granite and pegmatite, and readily undergo granitization, passing into the category of soaked rocks. In this respect, these two rock types are in sharp contrast to all other rocks of the region. No explanation seems to meet the conditions observed except the one that ascribes the easy penetration of these two rocks by granite chiefly to their original highly developed cleavage. The garnet-gneisses are metamorphosed shales, and in their recrystallized condition have a large mica content and are well foliated. Their thorough injection by granite is of the *lit-par-lit* type, penetrating along the cleavage planes. With the exception of certain hornblende gneisses, which are subject to the same sort of granitization, none of the other common Grenville rocks, limestones, quartzites or hard gneisses, have a good cleavage. Instead of being intricately and minutely penetrated by granite everywhere, these sediments resist such action, and are found cut by occasional large dikes, sheets or stocks of granite instead of showing the intimate penetration which the garnet-gneiss exhibits.

Martin has called particular attention to the plasticity of the garnet-gneisses under pressure, as shown by their intricate folding and puckering, so that they seem to be second to the limestones alone, among all the rocks of the region, in this property. Our own observations are in entire agreement.[1]

Variants from the general type of garnet-gneiss occur locally. Just east of Hailesboro the state road from Gouverneur to Fowler cuts through a low ridge of gneiss, near the west edge of the garnet-gneiss belt there, which departs from the normal type and is a very unusual and handsome rock in appearance. It is the ordinary injection gneiss though less injected than the average of the garnet-gneiss, but in addition it contains a great number of narrow, lenticular white bands of such fine grain as to give them a typical stony appearance, and also frequent, large garnets, of a purplish, almost amethystine color. These white bands are in strong contrast to the white granite sheets of the gneiss in their narrowness, their shortness and their fine grain. The garnets are of lenticular shape, elongated in the foliation planes, and are always in association with the white, stony bands, such bands always tailing away from one or both ends of the lens of garnet. No garnets were seen separate from the white bands, although many of the latter contain no garnets. In thin section the white bands are seen to consist of a felt of tiny sillimanite needles with interstitial quartz, the two in about equal quantity, and with abundant tiny zircons. The rock has not only been much squeezed, but was under much compression while the garnets were forming, as their shape shows, and the association of garnet and sillimanite bands suggests the possibility that the latter have arisen at the expense of the garnet, and that in the case of the bands in which garnet is lacking, it is because of its entire conversion to sillimanite. Such a conversion would, however, be most difficult to account for chemically, and probably the association is fortuitous, both being due to recrystallization along the foliation planes in a rock under high pressure. In plate 5 a view of a hand specimen of this rock is shown.

[1] N. Y. State Mus. Bul. 185, p. 38–39.

Plate 5

Garnet-gneiss from cut by Gouverneur-Edwards state road just east of Hailesboro, with large garnets. It is not much injected by granite and the white bands are composed of an intimate mixture of quartz and sillimanite.

Another type of gneiss found here and there in the general garnet-gneiss series contains less mica than the usual rock and in its stead carries considerable hornblende and pyroxene, and small garnets are more numerous than in the ordinary rock. Such rocks have probably arisen from bands of the shale which were originally more calcareous than the general run of the rock. In such a great thickness of clay shale as is represented in metamorphosed condition by the garnet-gneiss group, occasional beds with somewhat more lime content than the normal are to be expected.

Contact Garnet-Gneisses

Garnet-gneiss which is unmistakably of contact origin is found adjacent to some of the granite of the quadrangle. Such rock is best and most persistently shown along the east and southeast margin of the granite of the Reservoir hill sill, east of Gouverneur. The zone of contact rock is very narrow, in general from 1 to 5 feet in width, lying betwen the granite and the adjacent limestone. Along a portion of the east margin it widens considerably but even here it can not be mapped without exaggeration. The rock differs from the ordinary garnet-gneiss in having little or no foliation, in the abundance of good-sized garnets, which are generally of the skeleton type, and in the presence of pyroxene, tourmaline and pyrite, the whole making a rock of high specific gravity. It is frequently soaked by granite but, owing to poor foliation, the granite attack is very irregular instead of being of the even *lit-par-lit* type.

Amphibolites

Hornblendic gneisses of sedimentary origin, of contact origin, and of igneous origin occur throughout the Precambrian mass of northern New York. In the Gouverneur area only the latter type is found in quantity. The sedimentary gneisses of this sort occur as beds, usually thin, within the belts of hard gneiss, of limestone and of garnet-gneiss, very frequently in the first case, much less often in the others. They are found in many localities within the quadrangle but their aggregate thickness is not great. It is possible of course, that some or all of these seeming beds of hornblende gneiss may actually be of igneous origin, representing metamorphosed thin sheets of gabbro. In the great majority of cases, however, this seems most improbable. The contacts in many cases are not unduly sharp; no signs of cross-cutting have been seen at any contacts as would surely be the case sometimes were these true igneous sheets; and there seems to be no relationship between the occurrence of such beds and the proximity of nearby masses of gabbro-amphibolite. They are just as abundant at a distance from such masses as they are in their vicinity. Moreover, these sedimentary amphibolites seem to have a slightly different facies from those of igneous origin, although this is more easy of recognition than of description. The igneous ones are apt to have a more massive look, and sheetlike bands of supposed igneous origin are also found in the sediments, more particularly in the vicinity of the larger igneous masses.

Very little amphibolite to which a contact origin may be definitely assigned has been noted within the Gouverneur quadrangle.

IGNEOUS ROCKS

Gabbro-Amphibolite

The metamorphosed gabbros classed under this heading occur abundantly within the quadrangle and also to the north on the Ogdensburg quadrangle, but in many respects they are exceedingly puzzling rocks. They are everywhere closely involved with the porphyritic granites, occurring as frequent inclusions in them or themselves all cut to pieces by sheets and dikes of granite and dikes of pegmatite, and with the production of much soaked rock; that is, much of the granite contains more or less partly digested amphibolitic material, and much of the amphibolite itself is intensely granitized. A large part of the amphibolite is now really a coarse injection gneiss. Nearly all of the masses of this rock are bordered by granite on at least one side, and the gradation from one rock to the other is so intimate that the boundaries mapped between them are in the highest degree conventional. This is especially true in the case of the two largest masses of amphibolite within the quadrangle; the one which comes in at the southwest corner and runs northeast and east through West Fowler and Emeryville nearly to Talcville, together with its subsidiary masses to the southeast in the Fullerville region; and the other the masses which flank the Maple ridge granite in the northern part of the quadrangle. In each case the granite becomes more and more packed with amphibolite inclusions, and the amphibolite is cut by constantly more numerous and larger sheets and dikes of granite, as the border is approached, and the mapping of the boundary is based upon the estimate by the individual geologist of the line where the two rocks are in about equal quantity, with granite in excess in the one direction and amphibolite in the other. Obviously such a mapped boundary must depend in large measure on the individual judgment of the geologist; it must also be highly irregular. Hence there are portions of areas mapped as granite in which amphibolite actually exceeds granite in quantity, and amphibolite areas in which granite is in excess. It is also true that some boundaries are much sharper than others and can be readily mapped with a close approach to accuracy.

As mapped, the amphibolite masses seem to be either sills or stocks, the larger ones all belonging in the former category. Perfectly evident is the sill-like structure of the long, narrow mass which comes down from the Ogdensburg quadrangle, forms the western portion of Maple ridge, then passes down through North Gouverneur and north of Halls Corners and thence southwest on to the Hammond quadrangle. It is long and narrow and strikes and dips with the associated rocks. The similar structure of the West Fowler-Emeryville mass is equally evident, although this is not so long as the other, is associated with granite for its entire length, and curves back upon itself at its northeast end. There are also several smaller sills, each of which is associated with a granite sill. Other masses, however, such as that southeast of Fowler, that in the northwestern part of the quadrangle between the two branches of Beaver creek, that between East De Kalb and Old De Kalb, and that in the extreme northeastern part of the quadrangle, which runs over to the Stella mine at Hermon on the next quadrangle, are more or less broadly oval in ground plan and seem properly to be classified as stocks. Some of these wholly lack contact with granite, at least at the present-day surface.

All of these gabbro masses are highly metamorphosed and consist in large part of very micaceous hornblendic gneisses, full of quartz and pegmatite veins and blebs, much cut and soaked by granite and pegmatite, and thoroughly foliated. There are, however, abundant cores of much more solid amphibolite, with little or no foliation, whose massiveness leaves small doubt in the mind of the observer as to the igneous nature of the rock. The cross-cutting character shown frequently (more particularly by the stocks) furnishes the definite proof. This feature is beautifully shown at both the north and the south fronts of the stock in the northwest corner of the quadrangle, just east of Huckleberry mountain. The numerous, linear ridges of schist and quartzite to the north of the stock strike directly against its north face and, over a distance of a mile, are squarely cut off by it. The limestone to the south does not show the relation as plainly, outcrops being fewer and foliation poor, but it is also squarely cut off across the strike.

In these old gabbro-amphibolites of northern New York it is usual to find uncrushed cores of the rock which consist of pyroxene, hornblende and plagioclase feldspar (andesine to labradorite or bytownite). These grade into equally massive rocks in which the pyroxene has disappeared by alteration into hornblende, and the rock is a hornblende-plagioclase rock, with more or less black mica. These massive amphibolites grade, in their turn, into schistose varieties, with increasing amount of mica, and with it some quartz and alkali feldspar. Martin has described such pyroxenic, uncrushed gabbro cores from the identical rocks of the Canton quadrangle.[1]

None of the specimens of massive amphibolite collected by us on the Gouverneur quadrangle shows any trace of unaltered monoclinic pyroxene, but two specimens do show what seems to be wholly altered hypersthene. There is little doubt that pyroxenic varieties do occur within the quadrangle; but even without them there can be no question that the masses of solid amphibolite are altered gabbros, in which the original pyroxene has altered to hornblende, and the hornblende in its turn has begun to alter to biotite. They are essentially hornblende-plagioclase feldspar rocks (labradorite), with accessory apatite, ilmenite, zircon, biotite and pyrite, and often titanite, the feldspar constituting from 50 to 70 per cent of the rock in the various occurrences. Some biotite is always present and it rapidly increases in amount as the rock becomes more gneissoid. At the same time, the grain of the rock becomes broken down, the large feldspars becoming more and more granulated at the margins, with the uncrushed cores always under strain, while the hornblendes fray out into biotite scales. With these, quartz and some microcline or other alkali feldspar appear, and the rock as a whole is more siliceous. Martin's plate from the Canton quadrangle shows well the contrast in appearance between the massive and schistose varieties (plate 6), even though the one is injected by granite.

Since with this increasing schistosity injection and soaking by granite go hand in hand, it is often difficult to determine how much of the change in chemical and mineralogical composition is due to mere metamorphism and how much to the granitization. That the

[1] N. Y. State Mus. Bul. 185, p. 57, 61.

Plate 6

Upper figure. Mixed rock; typical example of modification of amphibolite by granite. Admixture here is extreme and not common. About one-eighth natural size.

Same location as shown in plate 11, lower figure; 1.3 miles southwest of Pierrepont.

Lower figure. Typical black amphibolite or hornblende gneiss; seamed with minute veinlets of hornblende (weathering in relief), the whole then cut by irregular masses of pegmatite. Scale about one-tenth natural size.

One and four-tenths miles east-northeast of Beach Plains Church, about 75 yards east of road.

formation of biotite and quartz from the hornblende goes on due to metamorphism solely, is unquestioned. The highly siliceous varieties of these mica-gneisses are always heavily granitized, but are mapped as gabbro-amphibolite even when their silica percentage approaches that of granite, since the amphibolite was plainly the original matrix of the rock.

These gabbro-amphibolites are the oldest igneous rocks of the region, being cut by, and occurring as inclusions in, all the granites. If the writer's belief that there are two granites of widely different age in the district be the correct one, the statement is still true, all the granite showing itself to be younger than the gabbro.

The most prominent features of these rocks are their susceptibility to granitic attack, and their close association with abundant granite nearly everywhere. The similar susceptibility of the garnet-gneisses has already been noted as well as the contrast with all other rocks of the district which both rocks show in this respect. Every amphibolite sill in the region is bordered by a granite sill, with a broad zone formed of an intimate commingling of the two rocks along the contact which defies exact mapping. Every amphibolite mass consists largely of very micaceous gneiss, intimately attacked by the granite. In discussing this phenomenon as found in the garnet-gneiss, it was argued that the high degree of schistosity of the rock was in large degree responsible for the ready attack upon it by the granite and the large scale formation of injection gneiss. Injection gneisses are coarser and ruder in the case of the amphibolite; the rock does not lend itself to the formation of such intimate *lit-par-lit* injection as the garnet-gneiss does. On the other hand, the granite minutely penetrates the amphibolite, with formation of soaked rock, more readily even than it does the garnet-gneiss. In the case of the amphibolite, it is thought that the composition of the rock gives an added reason for the granite attack upon it, the schistosity not being the sole reason. Both are igneous rocks; the granite is very probably a differentiate from a gabbro magma, and would therefore readily attack and assimilate gabbro material. It is also true that the mica-gneisses which have been converted into garnet-injection-gneisses have a composition sufficiently similar to the amphibolite to have permitted their ready soaking by the granite. Why the granite sills tended to select the contacts between the gabbro sills and the Grenville for their own lines of intrusion is not exactly obvious, but the fact that in the great majority of cases they did thrust in along precisely such situation, points to such contacts as unmistakably the zones of least resistance. The granite injected itself where the task was easiest; hence the contacts between the gabbro sills and the Grenville evidently furnished less obstacle to the intrusive forces in general than did the boundaries between the different Grenville formations, or the planes of separation between beds of the same formation.

Granites

In the great Precambrian area of Canada the present-day surface is much more widely occupied by granite than by any other rock. These granites occur in masses of all sizes but many of them are very large, seem to extend downward indefinitely, and are therefore classed as bathyliths. The Canadian geologists have long recognized that these granites were not all of the same age and have classed them in at least two groups according to this age difference. More recently a disposition has been apparent to recognize granites of three different ages.

In the smaller Precambrian district of northern New York granite does not bulk as large as in Canada and other intrusive rocks play a larger role, yet in New York also probably granite is more widespread than any other rock. Owing to the general similarity of the New York and Canadian districts, it would be natural to expect that granites of more than one age would be found in New York also.

In reporting upon the Geology of the Thousand Islands Region some years ago, Cushing showed that there were present on the Alexandria Bay and Grindstone quadrangles two granites of widely different age, the older of which was classed as Laurentian in accord with the Canadian usage prevailing, while the other was called the Picton granite. A third granite was also present on the Alexandria Bay quadrangle, but in only small quantity and in close relation to a red syenite, the Alexandria syenite. In contrast to the other two this was a porphyritic granite. It was unmistakably younger than the Laurentian granite, but its age relation to the Picton could not be definitely ascertained, although the Picton was found to hold inclusions of a porphyritic granite of similar type.[1]

In subsequently reporting upon the geology of the Ogdensburg and Brier Hill quadrangles Cushing showed that the extreme northeast point of the Alexandria granite bathylith of Laurentian age

1 N. Y. State Mus. Bul. 145, p. 36–43.

was found in the southwest corner of the Brier hill quadrangle, beyond which its possible further extent was hidden from view under a cover of Potsdam sandstone; and that in the southeast portion of the same quadrangle was another considerable mass, called the Macomb granite, which perhaps was a part of the Alexandria bathylith from which it was separated by Paleozoic rocks only, in any case, a closely outlying body and probably of the same age, although definiteness in the matter was impossible. It was also shown that there was a large body of granite in the southeast portion of the Ogdensburg quadrangle, the De Kalb granite, which extended south to Gouverneur and east to Canton, and which, while recalling the Laurentian granites in many respects, showed some puzzling and abnormal features; hence it was tentatively suggested that the mass was a combination of granites of two different ages, in part Laurentian and in part later. It was further shown that there were present in the southern part of the Ogdensburg quadrangle a number of sills of porphyritic granite of the same type as that connected with the syenite on the Alexandria Bay quadrangle, and also of the same type as the porphyritic granites which occur widely as a differentiation phase of the syenite bodies in northern New York. These granites were classed separately from the others and regarded as most certainly younger than the Laurentian. The relations shown were so obscure, however, that detailed consideration of them was left until the mapping of the Gouverneur sheet was completed, in the hope that further light would be shed upon them.

The Picton granite of the Thousand Islands region is a rather coarse-grained, nonporphyritic, red granite, which shows little sign of mashing, or of metamorphism, and in these respects as well as in its demonstrable field relations to the granite-gneisses regarded as Laurentian shows itself to be unmistakably younger. The fact that it also holds inclusions of porphyritic granite is evidence that it is younger than that rock. The porphyritic granite in its turn seemed surely a border phase of the syenite whose younger age than that of the Laurentian was shown along the western and southern sides of the syenite where it is in contact with granite gneiss for a distance. It both cuts it out across the strike and holds inclusions of it, just as it does with the adjacent Grenville beds.

No granite at all comparable with the Picton is found on the Gouverneur quadrangle, or on Ogdensburg and Brier Hill for that matter. Porphyritic granite, however, abounds on Gouverneur, and the older Laurentian granite is believed to be present, although the evidence is far from decisive, since the two rocks do not occur in contact as far as it is known. The belief in age difference is based on the different character of the two rocks, and their apparent identity with similar rocks on the Alexandria Bay quadrangle. The differences in character are as follows:

The granites classed as Laurentian are always thoroughly gneissoid, generally of fine and even grain, usually with very small mica content except where they have obviously soaked up amphibolite material, seldom if ever porphyritic, and containing amphibolite inclusions, often in great number, but with few or no other kinds of inclusions.

The porphyritic granites, on the other hand, are often coarsely porphyritic although they show also fine-grained, nonporphyritic phases which are often difficult to distinguish from the previous type; their mica content is usually large instead of small; while holding amphibolite inclusions in abundance they contain also many inclusions of the various Grenville rocks, even those of limestone; the types of inclusions held show a much more marked kinship with the bordering rocks than in the other case where the inclusions tend to monotonous amphibolites; and in many districts the porphyritic granites show a definite relationship with syenites, while such a relation is seldom, if ever, clearly shown in the case of the Laurentian granites. In addition, in the Gouverneur region, the porphyritic granites occur exclusively in sills, and the nonporphyritic occur as cross-cutting bodies.

On the basis of such differences the writer rather confidently classes the granite mass which lies directly north of the village of Gouverneur as Laurentian. All other granite of the quadrangle belongs clearly to the porphyritic group except for the De Kalb granite. The southern edge of this mass appears in the northeastern part of the quadrangle, whence it runs widely on to Ogdensburg and Canton. On the latter quadrangle in particular it has a sill-like form. While in doubt as to the proper grouping, his present opinion is that the mass is likely a combination of the two types of granite. If not, it should be classed with the Laurentian, in spite of its sill structure.

Gouverneur Granite

This name may be conveniently applied, for local use, to the granite mass just north of Gouverneur, an oval-shaped mass with northeast trend, and a long axis of about 5½ miles and average breadth of 1½ miles. It is for the most part surrounded by lime-

Plate 7

Amphibolite inclusions in Laurentian granite-gneiss, in exposure by the roadside 1 mile north of Gouverneur on Peabody Bridge road. These inclusions are mostly sharp, and not greatly soaked, but are much drawn out, in some cases ruptured and separated, and in the case of the large inclusion near the top, cut in very complex manner by the granite.

Plate 8

North edge of Gouverneur granite mass, 1 mile south of Rock Island bridge.

stone, the only exception to this being a couple of thin bands of hard schist within the limestone, which border the granite for a distance. The limestone is very massive and hence it is difficult to ascertain whether the granite is really a cross-cutting body or not. At the south, however, it certainly cuts out a band of hard gneiss and it seems clearly a small example of the generally oval bodies of granite of the bathylith type that prevail in the region, all of which are elongated in the general northeast direction of the strike owing to compression, and few of which show any tendency in the strike of the adjacent sediments to wrap round the ends.

This particular granite consists throughout of a quite fine and even-grained orthogneiss, consisting chiefly of feldspars and quartz with a very small mica content. It shows frequent coarser bands and frequent pegmatites, which diversify it somewhat but nevertheless are not in sufficient quantity to greatly affect its usual uniform and monotonous character. Inclusions are frequent but very unequally distributed and are almost without exception of amphibolite. These show the usual effects of granite action, being in all stages of elongation, of breakage and of soaking and absorption by the granite (plates 7 and 8). Toward the margins, near the limestone, the granite nearly everywhere turns from red to white in color, exhibiting precisely the same bleaching effect of limestone upon red granite that was described from the Thousand Islands region, although the white granite zone here is much narrower than that margining the Alexandria granite. The numerous granite dikes and plugs that cut the limestone are of white granite in every case seen, and are usually of coarser grain than the general body of the rock. There are several of these white granite knobs in limestone at the southwest end of the granite mass, just over the border on the Hammond sheet. There are others near Richville, also in limestone, which are on the trend of the major axis of the granite body and which, although at quite a distance from the main mass, are quite confidently classed with it.

The one considerable exception to the rule that the inclusions consist of amphibolite, occurs 2 miles north of Gouverneur on the Peabody bridge road, where there is a large inclusion of Grenville gneiss of the garnet-gneiss, mica-gneiss type, with a little interbanded limestone. This is the type of Grenville rock most likely to be incorporated in the granite without material change in character.

Our belief is very strong that this granite mass is old, is of the same type as that of the Alexandria Bay bathylith, and is to be classed with it.

Granite Sills

The granites of Huckleberry mountain, Maple ridge, Moss ridge and Reservoir hill are all sills, intruded into the Grenville sediments parallel to the bedding, and in the same category goes the great granite mass which runs diagonally across the quadrangle from southwest to northeast, together with its outlying tongues to the southeast. This great sill may be conveniently called the Hermon-Fowler sill, or for brevity the Hermon sill, because the greater part of its mass lies in that township.

The rock of these sills is of two somewhat contrasted types. The Hermon and Maple ridge sills are mostly composed of coarsely porphyritic granite, coarsest at the margins. But the granite of Huckleberry mountain, Moss ridge and Reservoir hill is comparatively fine-grained, with only traces of porphyritic texture. In fact, it more closely resembles the Laurentian granite than it does the usual porphyritic variety. Inclusions are few and the granite is very clean and homogeneous. The Reservoir hill granite is entirely inclosed in limestone, except for a narrow selvage of garnet-gneiss on its eastern border; the Moss ridge sill is narrow and intruded along the contact between limestone and garnet-gneiss except at its south end where it has garnet-gneiss on both sides and is sharply infolded with it; the Huckleberry mountain sill has limestone on both sides except at the north, where the limestone pitches down under quartzite and mica-gneiss and the granite is in contact with these.

The Hermon and Maple ridge sills contrast sharply with the others in having amphibolite on one contact. The amphibolite has been attacked with great energy by the granite, and a belt of soaked rock, often very wide, lies between the two so that no accurate boundary can be mapped. The Hermon sill abounds in inclusions, large and small, both of amphibolite and of Grenville, and these show also sharp contrast in respect to granite attack. The amphibolite inclusions are strongly attacked, those of limestone not at all or but little. The garnet-gneiss inclusions are of the usual injection gneiss, quite like the garnet-gneiss elsewhere. The identity suggests that these rocks had been converted into injection gneiss long before the intrusion of the granite of the sills.

Just what the relationship is between the soaking up of amphibolite by the granite, and the development of a coarsely porphyritic texture in the latter rock, it is difficult to say, but the field facts are decisive as to the relationship. That the rock of all the sills is of about the same age and consists of the same granite seems to us beyond question. In the sills which border amphibolite, however, the entire granite has incorporated amphibolitic material, the rock everywhere carrying much black mica, and often hornblende in addition, the two constituting from 10 to 20 per cent of the rock instead of the 5 per cent or less which is the mica content of the granite of the other sills. The granitized amphibolite is also full of large, porphyritic feldspars, and occasional ones are found in amphibolite only slightly granitized.

In the Maple ridge sill, where amphibolite forms the upper contact, the granite is coarsely porphyritic near the amphibolite and so remains for much of the width of the sill; but near the lower contact, which is against Grenville pyroxenic gneiss, it becomes finer-grained and much less coarsely porphyritic. Moreover, the narrow south end of the sill, where Grenville forms both contacts, is largely made up of fine-grained, nonporphyritic granite.

The narrow south end of the Hermon sill is also largely composed of fine-grained granite except in the immediate vicinity of the amphibolite beneath. The wider part of the sill is notably porphyritic, particularly at the north.

Although the narrow Moss ridge sill is chiefly of fine-grained granite, it also becomes coarsely porphyritic where it cuts into the amphibolite which forms part of its floor and lies between it and the Hermon sill. In fact, both the Moss ridge and the Battle hill sills lie so close to the Hermon that they doubtless connect directly with it not far underground (plate 9).

The ready attack of the granite on the amphibolite is no doubt due largely to the fact that the latter is an igneous rock. It is also quite gneissoid and hence more readily penetrated by the granite than many of the other rocks. The field evidence is also conclusive that much or all of the porphyritic granite is a mixed rock, having incorporated more or less amphibolitic material. The garnet-gneiss is also readily penetrated by granite with formation of injection gneiss, but does not seem to be actually digested by the granite as does the amphibolite, neither is the granite injecting it ever porphyritic. We are rather disposed to the view that the garnet-gneisses were injected by the Laurentian granite and were already in the condition of injection gneiss when the intrusion of porphyritic granite took place. In the Laurentian granites we have never seen any trace of porphyritic texture.

Porphyritic granites of this type show a close relationship to the green syenites over much of the Adirondack region, and are plainly differentiates of the same magma and of the same age. The syenite often shows porphyritic phases at its margins and the dikes which run out from it are often coarsely porphyritic. The syenite also shows large capacity to assimilate material from igneous rocks with which it is in contact. The associated granite is quite generally porphyritic. It is not intended to imply that this porphyritic character is generally due to attack on amphibolite, for quite the contrary is true. For most of the region the relations shown are those which formed at a greater depth below the surface than is the case here. The relations on the Gouverneur quadrangle suggest that the granite sills are mere upward tongues from a large mass of syenite and granite below ground, which deeper erosion would disclose. Here the Grenville cover still persists and these small masses of granite which have worked their way up into it from below, found it easier to follow the rock structures already in existence, and hence came up along the dip, forming sills. Differentiation had taken place below ground, with granite above, then syenite and likely gabbro beneath. The granite tongues were injected upward from the upper part of the mass. Even in these small masses the granite was sufficiently fluid to produce ready attack on the related gabbro-amphibolite, although it had little effect on the sediments. In the former case it became porphyritic, in the latter it did not. Farther east much of the Grenville cover is gone, owing to greater erosion because of usual higher altitude, and the surface rocks of the present day there represent a deeper zone than those of the Gouverneur quadrangle. Doubtless conditions similar to those here formerly existed at the surface farther east, but erosion has carried the material away. Here conditions such as those now found at the surface farther east are still underground. The porphyritic texture in the syenite and granite seems to us in general to be due to assimilative attack of the syenite or granite upon its border rock. This is more particularly the case when the border rock is an igneous rock. When the intrusive is in large mass, however, it also attacks certain sediments and becomes porphyritic, as on the Saratoga quadrangle where the attack is upon Grenville mica-gneisses.

While mere inspection of the areal map is sufficient to suggest the sill structure of these granites, field data to definitely prove the matter are by no means lacking. The evidence in regard to the structure of the Reservoir Hill granite is particularly clear. This sill runs out to a narrow point at the north, but at the south has a surface breadth of a mile and plunges down under the limestone there in a broad, rounded front instead of running out to a point. There are a couple of bands of hard gneiss in the adjacent limestone

Plate 9

West face of Moss ridge from the west, 2 miles east of Richville, illustrating the sharp relief of the granite above the limestone flat of the foreground.

Plate 10

Grenville limestone overlying granite of Reservoir sill just southeast of Gouverneur village, granite on right, Grenville hog back on left, dipping away from the granite. The contact between the two is about midway of the depression where the thin edge of green syenite is shown.

of sufficient resistance to erosion so that a prominent hog-back ridge of Grenville runs all around the south end of the sill (figure 3 and plate 10). The Grenville strike follows the granite margin all the way around, dipping outwardly from it at an angle of about 30°. As we pass around the end to the southeast front of the sill and go north along it, the southeast dip of the limestone rapidly steepens, becomes vertical, and then shifts to northwest, in conformity with the dip of the sill and of the limestone above it on the west. The relations suggest that the intrusive first arose at the south end of the sill, thrusting its way up along the dip and crowding away the limestone at the south into parallelism with its margin, and that, from this beginning, it gradually pushed its way to the northeast, along the strike.

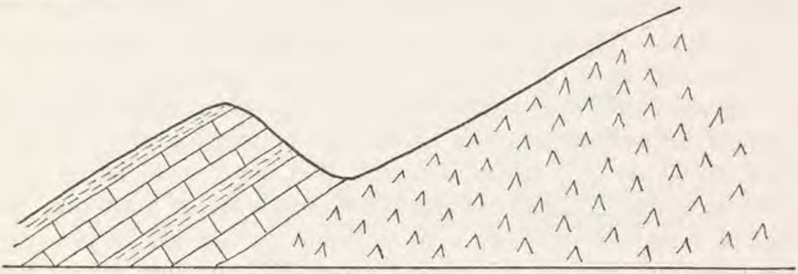

Figure 3 Section of Grenville limestone hog-back ridge at south end of Reservoir Hill granite sill.

At the southwest end of the sill, where the photograph shown in plate 10 was taken, the extreme upper edge of the granite, where it plunges down under the limestone, is of green color and greatly resembles the ordinary green syenite of the Adirondack region. It also contains both the peculiar green pyroxene and the bronzite which characterize the syenite, and allanite also. It is very quartzose, however, containing at least 15 per cent of that mineral. Evidence of contact action is shown by the development of tourmaline in the rock, but with that exception it is a quite characteristic sample of the acid phase of the syenite. There is very little of it, however. It is found only at the extreme south end of the sill, and has a thickness of but a few inches. It grades into the red granite within a thickness of a few feet, the intermediate rock being of brown color. This brown rock greatly resembles the ordinary weathered phase of the syenite elsewhere and no fresh material could be obtained from it. There is a small quantity of some wholly altered femic mineral in it which may have been pyroxene. This explanation is rendered quite probable by the fact that some hornblende is present in comparatively unaltered condition so that it is quite unlikely that the wholly altered mineral is hornblende. The brown rock grows steadily more quartzose as the red granite is approached, the granite holding approximately 25 per cent of that mineral as compared with 15 per cent of the green syenite.

On seeing these relations in the field our first thought was that here was a narrow chilled border of the granite sill. Unmistakable green syenite was found only at the extreme south end. Elsewhere along the southeast face of the sill, which is its bottom, a small thickness of altered brown rock is found, but no certain syenite. At the top of the sill exposures of the contact are rare, but in one locality, where blasting had been done along the roadside, the upper few inches of the intrusive were of gray color and contained pyroxene. No rock at all suggesting syenite was seen in the narrow northern half of the sill. All seen there is of monotonous red granite, and at the south all is red granite except for the thin selvage of possible syenitic material. In other words, there is no sign of differentiation within the sill, the bottom being of the same rock as the top. Without differentiation there could be no such thing as a chilled border, within the ordinary use of the term. No sign of differentiation or of a chilled border has been noted in any of the other sills, even in the great Hermon sill, although similar thin selvages of syenite may be present in them and have escaped notice because of lack of suitable exposures.

These granite sills today have steep dips, in conformity with those of the folded Grenville beds within which they lie. Did the Grenville folding precede the granite intrusion, or come later?

In an ordinary, flat-lying sill, in rocks not much disturbed, differentiation may take place in the intrusive before solidification, giving rise to less siliceous rock below and more siliceous above, with frequently a chilled border representing the quickly cooled, undifferentiated magma as first intruded. Where the beds were steeply tilted at the time of the intrusion, however, even if some differentiation took place in the liquid and less siliceous material collected downward, the contact between this and the more siliceous material above would not be parallel to the steeply inclined base of the sill but parallel to the horizon, and it would be practically impossible to tell in most cases, from any surface exposures, whether any differentiation had taken place or not. In this particular instance the thin selvage of syenite at the south end of the sill does distinctly suggest a chilled border, since it grades into the granite.

This close relation between syenite and granite here disclosed, is quite in line with the relations shown between the two rocks in many other localities in northern New York. The two rocks are closely related, are differentiated from a common magma, and are of substantially the same age, as has been many times demonstrated. But the relations shown at the Reservoir sill do seem to have a bearing on the question of the date of the folding of the Grenville rocks, as will be later considered under the caption of structural geology.

Diabase Dikes

Throughout northern New York the youngest rocks of Precambrian age occur solely in dike form. The usual rock of these dikes is a dense, black diabase, popularly known as trap. In a small area in Clinton county, centering around Rand hill on the Mooers quadrangle, the trap dikes are accompanied by another group of

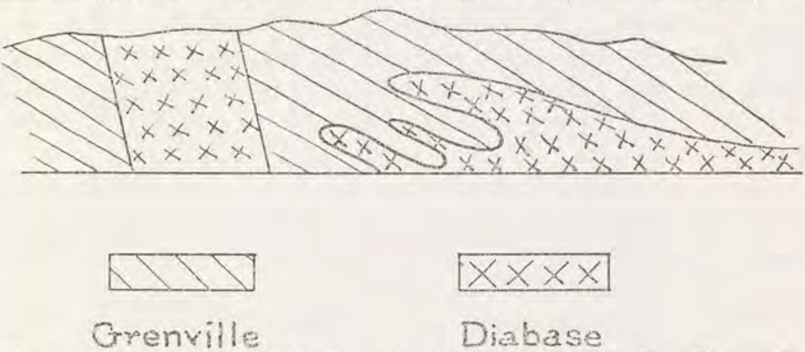

Figure 4 Diabase dike with irregular offshoots cutting Grenville gneiss, one mile north of Osborn lake.

more siliceous nature, usually of red color and of approximately the same age. Elsewhere only the trap dikes are found. These are very abundant in the eastern, and especially in the northeastern part of the region, and are also conspicuous in the Thousand Islands region, but between the two districts they are much rarer. Only two of these dikes have been noted within the Gouverneur quadrangle, one cutting the Grenville limestone in one of the quarries south of the village of Gouverneur, and the other in the extreme northern part of the quadrangle, 1 mile north of Osborn lake, in the tongue of higher land lying between the swamps of the two branches of Beaver creek. This dike cuts Grenville mica-gneiss. It is well shown in a rock cut by the roadside, and is unusual in that a branch of it cuts irregularly into the enclosing gneiss, instead of having the customary, sharply-defined dike form, as shown in figure 4. It is a quite typical olivine diabase, labradorite, violet-colored pyroxene, much olivine all gone to serpentine, magnetite with biotite corrosion rims, and good ophitic structure.

No doubt there are other representatives of these dikes within the quadrangle in addition to the two seen, but it is certain that they are very infrequent, and cut practically no figure in the general geology.

Potsdam Sandstone

There is no evidence that any Precambrian sedimentary formations, aside from the Grenville series, were ever deposited in northern New York. The evidence is clear that long-continued erosion of the region took place in later Precambrian time, with removal of much material and reduction of the land surface to comparative evenness. The surface thus formed was even, however, only in the large sense; in minor fashion it was quite uneven, the resistant granites, garnet-gneisses, quartzites etc., standing in relief from 100 to 200 feet above the lower grounds occupied by the limestones and weak mica-gneisses and rusty gneisses. On this uneven surface Potsdam deposition began, to be followed in its turn by other early Paleozoic formations.

Since these formations were laid down, erosion has removed all trace of them from the surface of the Gouverneur quadrangle, except that numerous, yet generally tiny patches of Potsdam sandstone still remain. Some of the later formations are still to be found at the surface, overlying the Potsdam, on the Ogdensburg quadrangle next north, and have been described in the report on that quadrangle. Some three dozen of these remnantal patches are shown on the areal map of the Gouverneur quadrangle, and there are at least twice as many more which are altogether too small to map on this scale. The largest mass present, located 1 mile north of Halls Corners, is less than a square mile in area.

These residuals occupy what were the very lowest spots of the old surface of deposit, spots where the sand deposit first began and where it accumulated to greatest depth. Since the Grenville limestone is the least resistant Precambrian rock of the quadrangle, being subject not only to mechanical erosion but also to chemical, owing to its slow solubility in rain water, it follows that practically all these residuals rest on Grenville limestone. They are most abundant in the great limestone belt which the Oswegatchie river follows from Oxbow to below Rock Island bridge, but they are found on limestone throughout the quadrangle.

Plate 11

" Dike " of Potsdam sandstone in Gouverneur limestone at the " four corners " just south of Rock Island bridge. This is a sand-filled solution fissure of the old Precambrian surface, now in relief because it does not yield to modern rain attack as the adjacent limestone does. This is one example of the many in the vicinity. Potsdam sandstone in place on top of the limestone occurs near by.

Prior to the beginning of sand deposition chemical attack of rain water on the limestone had not only lowered its surface but had also widened the joint cracks which reach down below ground from the limestone surface, precisely the same process now going on where bared surfaces of the Paleozoic limestones are exposed to weather attack, as they are in numerous places in the Thousand Islands and Ogdensburg districts. Into these widened joints sand sifted when sand deposition began, and these sand-filled cracks in the limestone, the sand now appearing as hard sandstone, may be seen in several places on the Gouverneur quadrangle, most notably at the Potsdam patches near Peabody bridge and at the patch just south of Rock Island bridge. The sandstone filling the cracks is today more resistant to erosion than the enclosing limestone, so that on bared limestone surfaces the red sandstone stands out in relief, and the resemblance is very strong to the appearance of dikes cutting the limestone (plate 11).

In some of the larger sandstone remnants a thickness of from 10 to 15 feet of sandstone is shown, but in most of them the thickness is much less. The rock varies much in the different exposures, and within the same exposure. It is sometimes red, sometimes white and sometimes red and white banded. It is usually very thoroughly cemented and vitreous, but locally the base, where resting on the limestone, is very calcareous and weakly resists erosion. Some coarse conglomerate occurs. Where this is basal the pebbles are apt to be very angular and to show little attrition; in fact, these basal conglomerates are very local, lie in hollows in the limestone surface, and seem surely to be so-called residual conglomerates. The angular pebbles are either of Grenville quartzite or hard gneiss, or else of vitreous sandstone. Where conglomerate occurs above the base the pebbles are generally much more rounded.

From Potsdam west to Clayton the Potsdam sandstone formation is rather thin, and in places where the Precambrian floor was highest on the granites and garnet-gneisses for example, it may entirely fail, and the Theresa formation lie on the Precambrian. East of Potsdam the formation rapidly thickens by the successive addition of beds at the base. In other words, the thin formation present from Potsdam to Clayton represents only the summit of the formation as it occurs more to the eastward. This upper portion consists largely of somewhat calcareous, not extra-resistant sandstone, of brown or white color, carries marine fossils sparingly and seems an unquestionable marine formation.

The sandstone found in these residual patches on the Gouverneur quadrangle differs from the above in color and in being very vitreous and hard, and noncalcareous except locally when in immediate contact with limestone. Angular blocks of hard red sandstone are also found as pebbles in the basal conglomerates. The phenomena are quite as they are in the Thousand Islands region and, as shown in the report on that district, suggest that this lower, hard sandstone is materially older than the ordinary Potsdam of the region, although it is not thought to be older than the basal portion of the Potsdam sandstone of Clinton county. It also seems to be a nonmarine accumulation. The evidence is not yet clear, however, as to the precise significance to be attached to the observed phenomena. It is quite certain that the deposit of the sand in these hollows of the old surface was not immediately followed by the sands which form the general Potsdam of the region, but that a time interval lay between. Whether this was a long interval, or merely a comparatively short one, is at present not known. The writer is of the opinion that the older sand here is the approximate equivalent of the basal portion of the formation as it appears in Clinton county, and that the other in like manner is equivalent to the summit, and that there is nothing here equivalent to the middle division of the formation in Clinton county. It is quite possible, however, that there is a break between the lower and middle divisions of the formation there, and the whole formation is very thick, at least from 1290 to 1500 feet. There is at hand today very little direct evidence in substantiation of the above opinion. The general Potsdam of this northwestern area is very thin and is the unquestionable equivalent of the extreme summit of the formation in Clinton county. The precise age of the basal sands of these hollows is an entirely open question.

STRUCTURAL GEOLOGY

Strike and Dip

The general strike of the Grenville rocks across the Gouverneur quadrangle is to the northeast and the prevalent dip is to the northwest. In these two respects the structure is in close accord with that of all the surrounding quadrangles of the immediate region. There is a considerable amount of swerving in the strike from place to place. Thus along the southern margin of the quadrangle nearly north strike prevails, while 2 miles to the north it has swerved to a direction more nearly east. The areal map plainly shows the general nature of the strike within the quadrangle, and its somewhat curving character.

In certain places strike directions which depart widely from this general one are found, but in the greater number of these the changes are local and rapid, the strike swinging round through an arc of 90° or more, and the explanation is to be found in the folded character of the rocks, as will be immediately shown.

The dips vary much in amount, but are seldom less than 25°, and over the greater part of the quadrangle average at least 45°, while often they are much steeper than that figure. Departures from the usual northwesterly direction are exceptional, are local, and again, in the great majority of cases can be shown to be due to the fact that the rocks are closely folded and that the folds often show sharp pitches, sometimes to the northeast, sometimes to the southwest. A study of the areal map would distinctly suggest the close folding of the rocks, even were direct evidence of this folding not obtainable in ample measure in the field.

Foliation

By foliation is meant the particular type of cleavage which is produced in rocks which are subjected to great pressure under such conditions that they crystallize, or recrystallize if they were already crystalline. In a mass of rock compressed in this fashion, the tendency is to diminish its extent in the direction of the pressure, and to increase it in the plane at right angles to the pressure. When a rock recrystallizes under such pressures, usually certain scaly minerals, such as the micas, or certain fibrous minerals, such as the amphiboles, are formed. The scales or fibres so produced will arrange themselves in accordance with the pressure direction: the flat sides of the scales will all be aligned in the plane at right angles to the pressure direction and the long axes of the fibres will also lie in this plane. Such an arrangement of these minerals results in giving to the rock a much more ready capacity to split in the direction of the plane at right angles to the pressure direction, than in any other direction, this capacity being a direct result of the peculiar mineral arrangement.

Obviously the perfection attained by such a cleavage will depend upon the production of either scaly or fibrous minerals in quantity in the rock. With diminution in their amount the cleavage becomes progressively less good. Thus the different schists and gneisses of the Grenville series show great variation in the perfection of their foliation cleavage, according to their mineralogic make-up. The pure limestones, and much of the granite also, lack such minerals, and show little or no foliation. Gneisses and schists are foliated rocks, the latter in general with more perfect foliation than the former.

Wherever known the Grenville rocks are completely recrystallized and strongly foliated. A certain combination of pressure and temperature conditions is requisite in order to produce such a complete alteration in a widespread and very thick rock series. Under very great pressure thorough recrystallization may be brought about with only moderate temperatures; with less pressures higher temperature is necessary in order to produce an equivalent effect. Extreme recrystallization such as the Grenville series has experienced is probably produced only under fairly high temperatures, irrespective of the pressure.

In districts where the rocks have been folded, as a result of strong, lateral compression, some recrystallization and development of foliation often takes place. Where the folded terrane becomes invaded by considerable masses of igneous rocks, very pronounced foliation may be induced. Such foliation will have steep inclination because it will form in the planes at right angles to the direction of lateral compression. It apparently can not everywhere lie parallel to the bedding planes of the sedimentary rocks, but must make an angle with them, especially along the crests and troughs of the folds.

The foliation of the Grenville rocks seems everywhere parallel to the bedding. Neither in New York, nor in Ontario or Quebec has any instance of discordance between the two ever been reported as far as I am aware. In the Gouverneur district this parallelism between the two is everywhere manifest, both possessing the same general northeast strike and northwest dip. That the rocks are strongly and closely folded will be later shown; nevertheless this parallelism persists throughout. It is difficult to see how this could be true had the foliation arisen as a result of the lateral pressures which caused the folding. Miller has used this parallelism as an argument to support his contention that the Grenville rocks are in general not greatly folded. To those who believe in their general folded condition, the conclusion seems irresistible that the foliation must have preceded the folding and that the rocks were already recrystallized and foliated at the time when they were folded, instead of having had the foliation produced as a result of the folding. Rocks already foliated, and with foliation and bedding parallel, could conceivably have become folded without the destruction of this parallelism.

Many years ago Van Hise directed attention to this concordance of foliation and bedding in the Adirondack Grenville, and was, as far as I know, the first to suggest that this might be due to mere downward weight of overlying rock, unaccompanied by side pressure. He says:

> In the formation of schistosity parallel to bedding, which occurs in part of the district, vertical shortening and consequently horizontal elongation below the level of no lateral stress, may have begun the process. When the rocks were subsequently folded the different degrees of strength of differently indurated beds evidently controlled the direction of differential movement, and the production of cleavage parallel to bedding was thus assisted.[1]

Recently W. J. Miller has discussed "Foliation in the Precambrian of New York," and R. A. Daly has referred to the region as an illustration of "load metamorphism" as incidental to an elaborate discussion of the classification of metamorphism.[2] Miller argues that "We are thus forced to the only alternative conclusion, namely, that the Grenville foliation was developed during the crystallization of essentially horizontal strata under heavy load of overlying material."[3] The fact that he bases a part of his argument on the contention that the Adirondack Grenville is essentially today in an unfolded condition, which does not correspond with our belief, does not vitiate the remainder.

Daly urges that the mere fact that foliation and bedding are parallel, in a terrane of recrystallized sediments, is *prima facie* evidence that the recrystallization took place under conditions of simple loading, the mere downward weight of the overlying sediments, and adduces the Adirondack region as one in which the process is illustrated.[4] He explicitly recognizes that in regions occupied by the most ancient Precambrian rocks the sediments rest on, and are much invaded by igneous masses, with the production of a considerable amount of contact metamorphism and a considerable bulk of injection gneisses, and that these effects are to be added to those of the load metamorphism.

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[1] 16th Ann. Rep't. U. S. Geol. Sur., p. 773.

[2] W. J. Miller Jour. Geol., v. 24, p. 587–619.
R. A. Daly Bul. Geol. Soc. Amer., v. 28, p. 375–418.

[3] *Op. cit.*, p. 597.

[4] *Op. cit.*, p. 400–9.

The writer quite agrees with this view of the origin of the foliation cleavage of the Grenville rocks. It should be noted, however, that the whole subject is involved and difficult, that lack of agreement prevails in regard to it, and that precise knowledge is lacking. The above view seems to us that most promising and plausible explanation of the correspondence between bedding and foliation, such as we have here, which has yet been offered. If it be true, or a close approximation to the truth, certain important consequences follow.

In the first place, it is necessary to assume that, at this very early period in the earth's history, its inner heat was much more prominently effective comparatively near the surface, than is the case today, and as has been the case all through the later part of geologic time; the rate of rise of temperature in passing beneath the surface must have been considerably more rapid than at present. This assumption is necessary because elsewhere Paleozoic and later rocks have been buried under a thickness of from 25,000 to 30,000 feet of superimposed rock material without undergoing any recrystallization whatever, or else in only trifling amount. There is no evidence that the Grenville rocks which today appear at the surface were ever buried any deeper than the above amounts; quite possibly the burial was not as deep. Daly explicitly admits the necessity for this assumption.

In the second place, since the Grenville rocks have been closely folded, under conditions of high lateral compression, if not everywhere, at least over a large part of the territory in which they are found, it follows that they must have been foliated before they were folded. Having already completely recrystallized under pressure, they either did not again recrystallize when they were folded under lateral compression, or such recrystallization as did then take place was controlled in direction by the already-existing foliation, and followed that, instead of conforming everywhere to the plane at right angles to the direction of compression.

The granite-gneisses of the Laurentian are also foliated, not strongly so because of their composition and hence small content of scaly and fibrous mineral particles, but as thoroughly as their mineralogic make-up allows. Their foliation is everywhere parallel to that of the bordering Grenville, and they are much more prominently and uniformly foliated than are the members of the later group of igneous rocks. The gabbros, now amphibolites, which preceded them, are much better foliated, because of their abundant hornblende and lesser, but still considerable, mica content. These gabbros are strongly infolded with the Grenville rocks and their foliation follows the curves of the folds. It seems likely, therefore, that their foliation also was produced under conditions of mere downward weighting instead of under lateral pressure.

It is quite possible that the intrusion of the Laurentian granites was responsible for a certain amount of the folding shown by the Grenville rocks; and it is quite probable that the granite intrusions occurred while the side pressures were in operation and the folding was going on. It is also in the highest degree probable that folding continued long after the granite injections had ceased.

Folds

Where rocks are subjected to pressure of sufficient amount and duration from the side, they shorten their extent in the direction of the pressure by wrinkling or folding, such folds trending in the direction at right angles to the pressure. In general rocks can not fold at or very near the earth's surface since there they are too rigid and brittle, so that they fracture rather than fold. Deeper down, under the load of a sufficient weight of overlying rock, they are less rigid and bend rather than break. The folding may be only gentle, but if sufficiently great pressure endures for a long enough time, the folds become increasingly more pinched and more tipped. Excessive pressures may so pinch them that the two limbs become nearly or quite parallel, the dip in the same direction and of substantially of the same amount on the two sides. Folding of this type has usually been styled " isoclinal " folding because of the similarity of dip on the opposite limbs. Where a series of rocks has been tightly pinched up into a succession of such isoclinal folds, and subsequently the folds have become truncated by long-continued erosion, the surface exposures will consist of successive rock beds with the same dip and strike. In recrystallized, nonfossiliferous rocks, such as those of the Grenville series, in which few or none of the individual beds present characters so definite as to enable the certain identification of the bed wherever it may occur, it becomes an exceedingly difficult matter to demonstrate that the rocks are actually folded. A series of unfolded rocks which had been tilted as a whole and then truncated by erosion would consist of successive rock beds with the same dip and strike, and would thus present a very similar appearance to the other (figures 5–8).

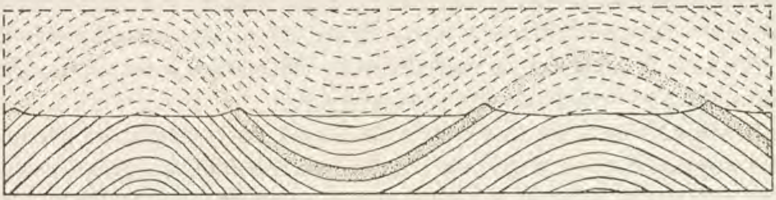

Figure 5 Diagram of gently folded beds which have been truncated by erosion, the upper dotted portion having been worn away; showing the broadly open character of the folds and the dips in opposite directions of the two lines.

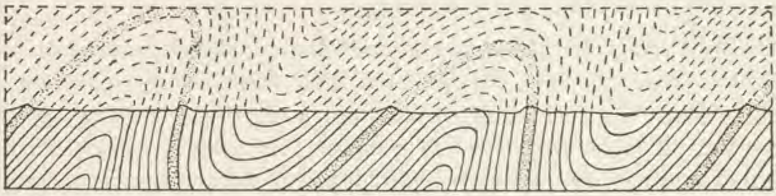

Figure 6 Diagram of more closely pinched folds, also truncated by erosion; folds somewhat tipped giving much steeper dips on one limb of a fold than on the other.

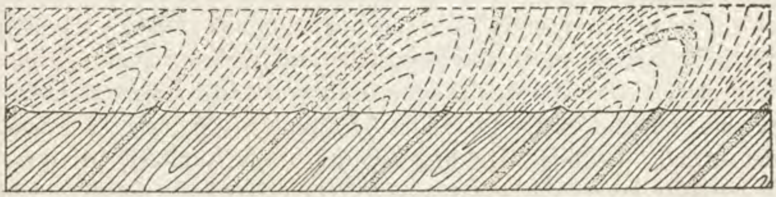

Figure 7 Diagram of very closely pinched folds, strongly tipped, and truncated by erosion; dips are all in the same direction and similar in amount; typical isoclinal folding.

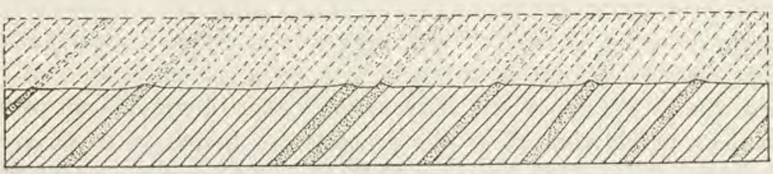

Figure 8 Diagram of tipped, but unfolded beds, truncated by erosion; dip of substantially the same amount and direction as in the case of the isoclinal folds of the previous diagram. In that diagram all the dotted beds represent different portions of a single folded bed, while in this they represent so many separate beds. The thickness of beds represented on the isoclinally folded series is comparatively small, while in this diagram it is very large. If the two structures are confused very erroneous ideas in respect to the rock thickness may result.

Most of the men who have worked in the field on the Adirondack Precambrian have come to the conclusion that the Grenville series is tightly folded, in isoclinal fashion. Thus Kemp, Smyth, Newland and Cushing have repeatedly stated this to be their view. More recently, however, W. J. Miller has urged that over much of the region these rocks are not strongly folded, and that such folding of this character as does exist is local only, instead of being regional, and is due to the local effects of igneous intrusions instead of to regional lateral compression.[1] Daly also has expressed the view that in many parts of Canada and of the Adirondacks the Grenville is not greatly folded, but lies rather flat and comparatively undisturbed. Miller has suggested a contrast between the Adirondack region and the Thousand Islands region in this respect, granting that the Grenville is more folded in the latter area than he thinks it is in the former.

Within the Gouverneur quadrangle the evidence that the Grenville beds are closely folded is exceptionally clear. The sediments are much less involved with igneous rocks than in most of northern New York, and occur in long and wide belts, with abundant exposures. These structures will be described, and their bearing on the general question then set forth.

Although there are many bodies of igneous rock within the quadrangle they are generally of small size, and many of them are sills instead of being cross-cutting bodies which do not at all interfere with or disguise the sedimentary structures. Larger bodies do interfere to the extent of causing some curvature in the strike of the sedimentary beds, but that is all. Across the northern portion of the quadrangle is a nearly uninterrupted Grenville section, broken only by the sills of amphibolite and granite which form Maple ridge.

As the areal mapping of the quadrangle proceeded, locality after locality was found where the general northeast strike, and northwest dip of about 40°, was interrupted by a sharp bend in which the strike became northwest and the dip northeast. Such a swing takes place at the Cole mine, for example, in the pyritic quartzite and the underlying limestone. These small folds always showed strong pitch, and seemed most naturally explainable as small, secondary, pitching folds on the limbs of larger folds. Such appear on the map in but few places, partly because many of them were too small to map on this scale, partly because they occurred within what are mapped as single formations, the contrasted beds being

[1] Jour. Geol., v. 24, p. 588–93.

too thin for separate mapping. There are many such small folds, for example, within the belts mapped as impure limestones.

Another frequent observation was the disappearance of a given bed, or formation, along the strike. Here also the impression invariably given was that the disappearance was due to the carriage of the bed or formation below ground because of a pitching fold of which it was the central member. In places it was possible to actually demonstrate this, and to follow the bordering bed as it folded around the end of the disappearing one.

On the western border of the quadrangle several examples of unmistakable pitching folds were seen. A small syncline in hard gneiss, with limestone above and below, with southwest pitch, may be seen at the west margin of the sheet, just north of Natural Dam. A similar one occurs 2 miles farther north, and to the prolongation of this belt on the Hammond sheet Buddington has recently referred in the following words:— " a narrow belt, here called the Laidlaw belt, in the town of Antwerp, running from Halls Corners to Oxbow — this is simply the northwest limb of an isoclinal syncline of gneiss of which the Keene-Antwerp belt is the southeastern limb, the two limbs connecting with each other along the strike at Halls Corners."[1] It is the apex of this syncline which lies within the Gouverneur quadrangle, to which reference is here made; and it is to be observed that Buddington's interpretation of the structure is precisely the same as that here set forth, although a result of independent and of subsequent work. There are other excellent examples of the same sort of thing on the Hammond sheet.

Much the clearest evidence of larger scale Grenville structures was obtained in the southeast portion of the quadrangle, and more particularly along the contact line between limestone and garnet-gneiss to the south of Edwards. Much of this territory Newland and Cushing visited together. We were quite in harmony in regard to its testimony, and Newland has since published a section across the belt, in illustration of its structure.[2]

A great belt of garnet-gneiss with a width of 3 miles or more comes in from the south on the southeast corner of the Gouverneur quadrangle. To the north this great belt pitches down and disappears under the limestones of the Edwards belt. It not only pitches down as a whole, but its western margin is characterized by infolded tongues of limestone and garnet-gneiss, which are minor folds on the

[1] N. Y. State Defense Council, Bul. 1, p. 3–4.
[2] N. Y. State Defense Council, Bul. 2, p. 43.

west limb of the large one, and show the same pitch. The strike is somewhat east of north and the dips are to the west and fairly uniform, some 35° to 45°. A very prominent narrow tongue of garnet-gneiss is shown on the Gouverneur map, its final termination being just over the border on the Russell quadrangle, with a great infolded tongue of pure limestone separating it from the main mass of the garnet-gneiss, the termination of which also lies on the next quadrangle. Outcrops are numerous, and the field evidence seems clear that the garnet-gneiss forms a great anticline, with many subsidiary anticlines on its flank, and that the limestone overlies it. It is the downward pitch of these subsidiary anticlines to the north,

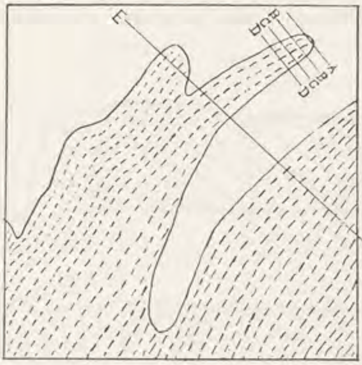

Figure 9 Sketch of the folded limestone and garnet-gneiss south of Edwards (garnet-gneiss dotted, limestone unshaded), showing the nature of the boundary between the two and the positions of the sections shown in figure 10.

and their disappearance one by one beneath the limestone, that is responsible for the peculiar contact line between the two formations, and for the increase in breadth of the limestone belt at the expense of the garnet-gneiss in going north. The most decisive evidence of the folding and of its nature was obtained where the limestone wraps around the ends of these disappearing tongues. In figure 9 a sketch of a portion of the contact between these two formations is shown, on which appear the section lines of the sections shown in figure 10.

These sections show clearly the nature of the evidence. In the section *A—A*, made near the northerly point of the garnet-gneiss, the limestone west of the gneiss dipped to the west while that east of it dipped to the east, and their strike was somewhat divergent; in fact, as the limestone was followed around the front of the garnet-gneiss tongue its strike steadily swerved in parallelism with the contact.

As the east margin of the gneiss was followed to the south from the section line *A—A,* this easterly dip rapidly steepened as in section *B—B,* reached and passed the vertical as in *C—C,* and thereafter became a west dip which steadily became less steep, till it reached substantial accordance with the dip on the west side. Section *D—D* shows a close approximation to this condition, and also

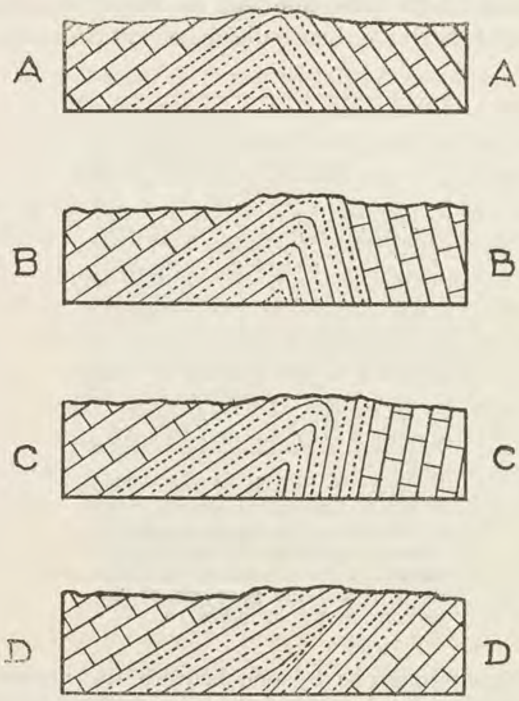

Figure 10 Sections A, B, C, and D across the end of the pitching fold of garnet-gneiss.

represents a section across an isoclinal fold. The sections simply represent stages in a continuous process. Folding is suggested by such a section as *D—D,* although by itself it would be impossible to say whether the structure was anticlinal or synclinal; but when combined with the other sections the evidence becomes conclusive that we are dealing with a closely pinched anticline which pitches north.

These sections are across one of the subsidiary folds on the west limb of the main fold. Sections across the downward pitching snout of the main fold, on the Russell sheet, however, are of precisely the same type. It follows that the limestone of the Edwards belt forms a syncline, and that the tongue of limestone running southwest into the garnet-gneiss, the one shown in the sketch (figure 11), is a minor syncline on the flank of the anticline of gneiss. Newland has published a section to express his conviction that the Edwards limestone belt has synclinal structure;[1] and our section *E—E* (figure 11) which runs across two of the subsidiary garnet-gneiss tongues and shows part of the main anticline at the extreme east, gives our interpretation of the general structure, on what seems to us conclusive evidence.

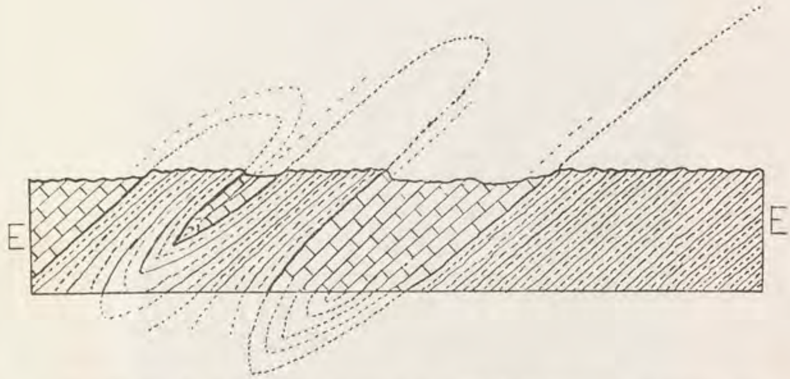

Figure 11 Section E-E, showing two infolded minor synclines of limestone, between anticlines of garnet-gneiss, on the flank of the great fold of garnet-gneiss which is partially represented at the right.

Within the Edwards limestone belt, 1 mile southeast of Talcville (see areal map), a considerable knob of rusty gneiss is domed up. The structure is clearly that of an anticlinal dome, arched up within the limestone as a subsidiary small anticline in the bottom of the limestone syncline, and with a very rapid pitch below ground at both ends. Buddington also considers, from independent work, that the structure here is anticlinal.[2] The general dip of the schist and of the surrounding limestone is to the northwest except at the ends of the dome, where the schist pitches below ground. At these points the limestone wraps round the ends of the schist and variations in dip similar to those which have just been described occur.

[1] N. Y. State Defense Council, Bul. 2, p. 43.
[2] *Op. cit.*, p. 4.

Talcville Cuts

The Edwards branch of the New York Central and Hudson River Railroad runs through a narrow belt of hard gneisses, for a mile and a half just east of Talcville, a belt which lies within the limestone series and is closely bordered by the talc and zinc deposits. The surface of the belt is moderately rugged and the railroad has made frequent rock cuts. Two of these cuts are squarely across the ends of minor folds, with strong northerly pitch, which show excellently in section. A sketch of the relations shown in one of them appears in figure 13, and the other is very similar. The section is near the nose of the fold so that, while the dip on the west limb is normal, that on the east has not yet swung around to parallelism

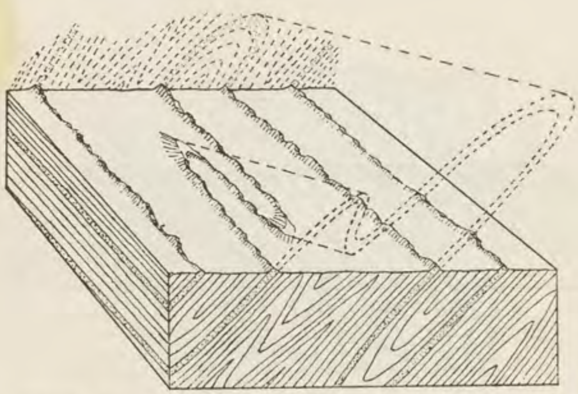

Figure 12 Section and sketch of pitching isoclinal fold to illustrate the manner in which pitch carries a bed below ground; the line of outcrop of the ridge of resistant rock formed on the left flank of the main anticline is very similar to the margin of the garnet-gneiss tongue as shown on the sketch in figure 9.

with it, and the conditions represented are similar to those shown in section *A—A* of figure 10. The rock face in the cut is 10 feet high and many yards long, so that a fold of moderate size is here shown, instead of a mere plication.

Plications

Many of the Grenville beds are intricately contorted and plicated. Miller states it as his experience that such plications are largely confined to the limestone beds.[1] Our own experience is so dia-

[1] *Op. cit.* p. 505.

Plate 12

Contorted color-banded limestone of Grenville series by the roadside 1 mile northwest of Pine Hill, Hammond quadrangle.

metrically the opposite that a special point must be made of it. It seems to us that the limestones show such structures least well of any of the Grenville beds, and that the quartzites, especially the thin-bedded members of the group, show them best. An occasional banded limestone, such as that shown in plate 12, does show them well, but that particular picture was taken because of its exceptional nature. Such thoroughly and beautifully plicated limestones as those of the Hastings series in Ontario consist of rapid alternations of limestone and of para-gneiss, and not of pure limestone; and such impure limestones do often show plications excellently.

The evidence seems quite conclusive that the Grenville rocks, across the entire width of the Alexandria Bay, Hammond, Gouverneur and Russell quadrangles, lie in a series of closely pinched, isoclinal folds. On the Canton quadrangle, just north of Hermon, Martin reports the Grenville as closely folded, with some folds of unusual type.[1] On the Lake Bonaparte quadrangle, next south of

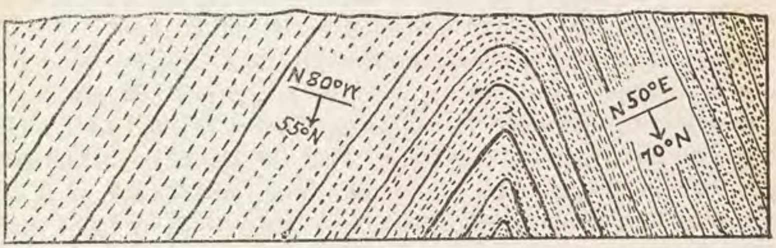

Figure 13 Section in railroad cut not far east of Talcville, across the nose of a pitching isoclinal fold in hard gneisses.

Gouverneur, Buddington reports similar folding. These are the quadrangles in northern New York in which the Grenville series is best developed, most widespread, and least cut away by igneous rocks, therefore the quadrangles in which the problem of Grenville structures can be most successfully attacked. It is to be noted that the observed close folding obtains across a width of four quadrangles; that a width of only six additional quadrangles intervenes between the Russell quadrangle and the Paleozoic rocks along the shores of Lake Champlain; in other words, that 40 per cent of the width of the New York Precambrian is comprised in these four quadrangles. Is not then the query justified: Where does the Thousand Islands region end and the Adirondack region begin? As a matter of fact, any separation between the two

[1] *Op. cit.*, p. 590–93.

regions is purely fanciful. The western district has been less deeply eroded than the east, and hence shows more Grenville, less igneous rock, and a slightly less degree of metamorphism; but there is a gradual passage from one district to the other in all these respects; they belong together in all aspects except the topographical; and no man can draw a satisfactory geologic boundary between the two.

The general problem of the structure of the Grenville rocks can be stated something after this fashion: Here is a great series of very old, thoroughly recrystallized sediments which, at least in New York, rests always on a floor of various igneous rocks, all of which are demonstrably younger than it is, and which have invaded it from below. The present surface, in the eastern part of the region, consists much more largely of the igneous rocks than of the Grenville, and the latter occurs in separate masses, surrounded and enclosed by the intrusives. There is more Grenville remaining in the western half of the region, and in the western third it equals or exceeds the intrusives in surface extent, and the Grenville areas are more or less well connected with one another.

The general structure of the separate areas suggests usually a great monocline. The dips vary much in amount and are sometimes quite flat, although usually of 30° or more; and over much of the district equal or exceed 45°. If the structure be *actually* monoclinal then the series has an enormous, an unheard of thickness. While it is unquestionably a very thick group of rocks, such thicknesses as 94,400 feet, obtained by direct measurement on a supposed monocline under unusually favorable conditions, thicknesses several fold in excess of those of any other known sedimentary group, and thicknesses obtained by the measurement of what is confessedly only a part of the series, neither base nor summit showing and certain well-known rock types which belong to the series being absent in the section, can not but throw doubt on the verity of the suggested structure.[1]

Eroded isoclinal folds closely imitate monoclines, and can not successfully be discriminated from them in cases in which it is difficult, or impossible, to recognize individual beds from place to place. If we regard the Grenville series as isoclinally folded, we

[1] In their account of the measurement of this section Adams and Barlow state that it is impossible to determine whether repetition by isoclinal folding has taken place or not, as there is no horizon sufficiently well marked to permit of its being recognized in a repeated series. They also give 45° as the average dip, and state that, since folding has nowhere brought up the basement on which the series was deposited, it must be very thick, even if isoclinally folded.

are relieved of the necessity of assuming for it such prodigious thicknesses.

Miller has described several instances in which masses of Grenville lie upon syenite or granite after the manner of a roof, in which it seems to him certain that the Grenville beds have been domed over the uprising magma, and that their present dips are due to this doming.[1] We find no fault with this interpretation; it seems to us obvious that the great igneous masses must have often produced effects in the overlying Grenville such as he describes. The question is do these effects show plainly that the prior condition of the Grenville was an unfolded one? That does not seem to be a necessary conclusion.

It seems to us demonstrated that the Grenville rocks, in the western 40 per cent of the Precambrian of northern New York, are pinched into tight folds. It seems probable that they were first foliated under load metamorphism, and subsequently folded. It seems to us probable also that much of the folding took place during and after the intrusion of the Laurentian granite-gneisses, but before the date of the later intrusions. These latter, of the anorthosite-syenite-granite-gabbro series, lack the predominance in this northwestern region that they have in the eastern Adirondacks, and occur mostly as relatively narrow sills, whose position was controlled by the Grenville structures already in existence. The contrast between the two districts is thought to be chiefly due to the greater erosion which has affected the eastern one; conditions such as prevail at the surface in the east today are thought to occur well below ground to the west; the intrusive sills are upshoots and offshoots from the greater mass of the intrusives beneath. At a depth of a mile or two beneath the surface of the Gouverneur quadrangle, it is inferred that there would be a vastly greater extent of the intrusives and much less Grenville, and the Grenville would occur in separate patches amid the intrusives, quite as it does at the surface in the east today. The zone corresponding to the present surface in the west was formerly present in the east also, but long since disappeared through the agency of erosion.

If an isoclinally folded series, such as we conceive much of the Grenville to be, were invaded from beneath by great, upwelling masses of intrusive magma, the deeper portions of the sediments would be much more affected than would those more remote. The upper surface of the intrusions would be very irregular, great

[1] *Op. cit.*, p. 590–93.

wedges of Grenville would remain in the depressions between the higher protrusions of the magma, large masses of Grenville would break away and sink somewhat in the molten mass beneath, and these masses would tend to be variously tilted. Some of them would have their initial dips steepened in the process, others would have them lessened. Masses of the latter type might well appear to consist of unfolded sediments with very gentle dips.

We must either admit that the Grenville series has a stupendous thickness, many times greater than that of any other known sedimentary rock group, or else conclude that much of it is closely folded. The only possible alternative is to hold that what appears to be bedding is not true bedding, and hence gives a deceptive idea of the true thickness. We do not know of a vestige of evidence in favor of this conception. Since the condition of close folding is demonstrable over a considerable portion of northern New York it seems to us reasonable to infer that such a condition prevails over much of it. The gentle dips and the doming of Grenville masses on the intrusives which occur locally in the eastern region may be due to the tilting of certain blocks into more nearly horizontal position, and to the tendency of the intrusions to utilize bedding and foliation planes as their points of easiest attack.

It is not contended that the Grenville rocks are everywhere closely folded, but it is urged that such folding does prevail over great areas. Agreement with Miller in his contention that the Grenville on the west is more strongly folded than on the east, is not difficult; but from that it by no means follows that his view that, in the latter region, a generally unfolded condition exists is the true one. It is in the highest degree probable that the degree of Grenville folding varies from district to district; that close folding prevails in some belts, gentler folding in others, and little or none in yet others. It is a part of the work of the future to specifically separate and delimit the areas of each type. Today we possess merely enough knowledge to indicate that the three types of structure do exist, and that it is unsafe to generalize upon the structure of the whole series everywhere, from the structures found to obtain in a limited region. This applies equally to New York and to Canada. It is true, however, that close folding often prevails, and that in districts where the dip is steep and where the assumption of an unfolded condition necessitates the belief in a prodigious thickness for the series it is highly probable that the rocks are really folded.

Present opinion in Canada upon the question may perhaps be sufficiently indicated by quotations from two letters received, one from Adams and Bancroft, the other from W. G. Miller and Knight. Adams writes concerning the view of Bancroft and himself:

We agree that all that can be said is that in the explorations which have gone forward in the Grenville series during the period of approximately 60 years which has elapsed since the publication of the Geology of Canada in 1863, it has been ascertained that the whole Grenville is not everywhere sharply folded as Logan represented it in the original Grenville area, but that there are great tracts of the country over which the strata of the Grenville series are either flat or lie in very gentle undulations. Elsewhere, of course, they are sharply folded, but the question of the relative areas of the sharply folded and the flat portions of the series is a matter concerning which no definite statement can be made at present.[1]

Miller and Knight say:

Although we studied in a general way the question of folding throughout the Grenville of southeastern Ontario, we nevertheless have not attempted to determine whether close folds predominate, or whether gentle folds are more common. But at the same time it may be said that, as a rule, the Grenville beds now occur in vertical or steeply inclined attitudes. In our work we studied with *special* care the question of folding in but two small areas, namely the Madoc area and the Queensboro pyrite area. In both areas there are examples of very close folding and also of gentle folding.[2]

Miller states in addition:

I have seen very little Grenville that is not much disturbed. A pseudo-bedding has sometimes been developed which is confusing and might lead one to infer that rocks had not been much disturbed. The original structure in the limestones has in some cases been entirely destroyed.

In comment it may be pointed out that the district in southeastern Ontario, in which Miller and Knight report usual steep dips, and much folding, is closely adjacent to the western Adirondacks, in which our results are quite similar; that in the more easterly districts which are included in the Adams and Bancroft statement large sized tracts of unfolded Grenville occur; and that W. J. Miller contends that the general Grenville in the eastern Adirondacks is unfolded. There does seem ground, then, for concluding that along one great belt, comprising the western Adirondacks and southeastern Ontario, the general Grenville is much folded, and

[1] Letter of March 8, 1918.
[2] Letter of March 4, 1918.

that in a more easterly belt considerable unfolded Grenville occurs. It is quite probable that some of the Grenville of the eastern Adirondacks is comparatively unfolded, but when its fragmentary character is considered, together with the fact that many of the fragments seem to have been completely broken away and completely inclosed in the intrusives, and have probably been variously tilted, it seems to us in the highest degree unsafe to contend that an unfolded condition is the prevailing one.

Granite Sills

That the porphyritic granite of the quadrangle occurs in sills has already been pointed out. Certain features of the occurrences, however, lead to the belief that the Grenville series was already sharply folded, was in substantially its present attitude, at the time when the granite was injected. In other words, the folding is older than the granite is. The granite sills were not tipped as a result of regional folding after they were intruded, but the granite was injected into beds already folded and with steep dips, and worked its way upward following the dips.

The Grenville inclusions in the sills, particularly the large inclusions in the Hermon sill, give important testimony. Take the Tanner creek inclusion for example, the largest and most significant of all. This inclusion is nearly 5 miles in length, and in width between ¼ and ½ mile. Narrow as it is, it consists, throughout its length, of a central band of limestone, bordered by garnet-gneiss on each side. The garnet-gneiss is not of the contact type but is the ordinary injection gneiss which constitutes the general run of this rock. The inclusion presents precisely the same structural combination that is found southeast of Edwards, the minor synclines of limestone in garnet-gneiss on the flanks of a larger fold. This Tanner creek inclusion seems to us to unquestionably have synclinal structure. With fluid granite working its way upward along the dip it is not only easily conceivable that the bottom of such a narrow synclinal trough might readily split the ascending intrusive, but it is quite difficult to see how it could avoid doing so.

There are a host of Grenville inclusions within the Hermon sill. Most of them are too small to map on this scale, though several of them do appear on the map. Their strikes and dips are in harmony with one another and with those of the Grenville beds away from the intrusive. The granite shows little sign of having experienced the pressures which would be necessary to so sharply fold a thick sedimentary series. It has unquestionably been squeezed. It is somewhat foliated, and the porphyritic feldspars are somewhat granulated, especially locally. The rock as a whole, however, is not much crushed, and the great number of the big porphyritic feldspars show little or no granulation. The rock has undergone a certain amount of compressive stress since its injection but nothing in comparison to what it would have experienced had it been folded along with the Grenville beds. Just how, as a result of such folding, a synclinal trough like that along Tanner creek could have come into existence as an inclusion in its present attitude, is quite beyond our powers to imagine. It seems to us quite clear that the concordance of strike and dip shown by all the inclusions points to the fact that the present surface exposures are very nearly at the extreme summit of the granite invasion, that it is practically all yet below ground, that the granite sills represent the extreme upper limit of the intrusion, that the Grenville inclusions were comparatively undisturbed parts of the old roof, the bottoms of down-folds in the overlying sediments, having almost precisely their present attitude at the time of the granite injection.

The structure shown by the sediments at the end of the sills, where they wrap round the intrusive as though pushed out of the way by the rising fluid, seem to us to point to the same conclusion. In particular, such conditions as are found at the south end of the Reservoir sill seem to us explainable on no other hypothesis. The Grenville hogback there, already described, is a structure conditioned by the upper surface of the granite intrusive. Then the thin selvage of greenish syenite there emphasizes this conclusion. It looks like a very narrow chilled border, but can not be such unless some differentiation took place within the sill, after intrusion but prior to solidification. Both bottom and top of the sill are exposed, however, and there is no sign of such differentiation aside from the chilled border. The bottom of the sill is composed of the same granite as is the top. If the sill had been originally flat-lying, intruded into undisturbed, unfolded Grenville rocks, then the evidence would be clear that no differentiation had taken place, and we should lack any reasonable explanation of the chilled border. If the intrusion took place into rocks previously folded, then differentiation in the sill would not take place parallel to the top and bottom of the sill, or rather parallel to the underlying and overlying sediments, but rather in the horizontal plane and, except for a narrow chilled border, nothing but granite would be found in the upper part of the steeply inclined sill, that part which is today exposed at the surface, and the syenite would be found well below the surface.

It therefore seems to us that we have in the Gouverneur quadrangle an example of one of the syenite-granite bodies so common in northern New York, in many of which the evidence is absolutely clear that they represent differentiation phases of the same magma; that here the uprising magma came into a cover of closely folded Grenville; and that because of the close folding somewhat unusual results were obtained. Granite sills are not common. Granite commonly works upward rather than sideways. From the top of granite bodies numerous dikes work their way upward, but in these closely folded rocks here the rising granite utilized the bedding planes, already steeply inclined, as the easiest upward path, so that what would ordinarily have been dikes here become sills. The main body of intrusive here is entirely below ground. In these sills we have merely small uprising tassels from the main mass, into the overlying Grenville cover. The Grenville was folded before the time of these syenite-granite intrusions. The time of folding was no doubt more nearly coincident with that of the earlier amphibolite and granite intrusions, here called Laurentian.

ECONOMIC GEOLOGY

General Considerations on the Occurrence of the Ores and Minerals

The area covered by the Gouverneur quadrangle in southwestern St Lawrence county is a notable mineral district. The bounds of the mineralized section somewhat exceed those of the map itself, but the Gouverneur quadrangle is central and fairly representative of the general character of the entire district. Many of the minerals recorded in Dana's Manual and other reference works on mineralogy for St Lawrence county may be found within the area, and some of the occurrences are not duplicated outside. Few districts anywhere in the eastern part of the country provide so much of variety and interest to the student of mineralogy and economic geology and at the same time in such accessible and inviting environment. Practically all of the important localities that are on record are opened mines or quarries or prospect workings, situated within an hour's distance at most from the village of Gouverneur. This place is headquarters for most of the mining operations in progress in the district and the general commercial center for western St Lawrence county, which is a fertile agricultural region.

The Gouverneur area, as has been shown by Cushing in his discussion of the geology, is a part of the Adirondack province, which itself belongs really to the Laurentian region of Canada. There is no close connection between the Adirondacks and the Green mountains which are separated from them only by the Champlain basin or with the Appalachian system in general that embraces all of the other upland and mountainous parts of the State. On the other hand, no natural break intervenes between the Canadian Laurentian region and the Adirondacks; the same Precambrian formations may be traced from the interior plateau district of St Lawrence county across the Gouverneur sheet and to the Hammond and Alexandria Bay quadrangles whence they extend to the St Lawrence river and reappear on the north bank to spread out west and north over an immense tract in Quebec and eastern Ontario.

The relationship, naturally enough, extends also to the mineral occurrences. The closest similarity exists in regard to many of the deposits, like those of talc, pyrite, zinc and iron ores, found in the Adirondacks and the part of Canada north of the St Lawrence river, evidencing a certain uniformity of geological surroundings. The comparison, however, may not be pushed so far as to indicate an identity of conditions in the two regions, for the Adirondacks cover a small area in comparison with the whole Laurentian highland and are lacking in representatives of some of the important formations of the area to the north, as well as, of course, their associated mineral deposits. There is no basis on geological grounds for expecting deposits of nickel, cobalt, silver or gold in the Adirondacks, such as give so considerable support to the mining industry of eastern Canada.

The rocks of the Gouverneur district belong to the same formations that characterize the geology of the interior Adirondacks, as has been explained already in the preceding section of this report. Although there is thus no line of demarcation existing anywhere between the highland proper and the area under consideration which has a surface of low relief mainly between the limits of 400 and 800 feet above tidewater, there is a considerable difference apparent in the general distribution of the rocks when their outcrops are outlined on the map. The interior Adirondacks are constituted predominantly of the hard massive rocks of igneous origin, that is, granite, syenite, anorthosite and their gneissic phases whereas the limestones and schists of the Grenville series play a subordinate role. In St Lawrence county the relations are so far changed that the sedimentary beds of limestone (marble) schists, and feldspathic or quartzose representatives of the Grenville have an important share in the surface geology, spreading out around Gouverneur in several considerable belts that altogether cover more than one-half of the surface of the quadrangle. The basic igneous rocks of the gabbro-anorthosite division are unimportant areally, and the main representatives of the igneous class are granites and their offshoots of pegmatite.

There are probably at least two varieties of granite of separate periods of intrusion represented in the district, but by far the predominant sort is a reddish coarse variety which Cushing calls the porphyritic granite, distinguished by a considerable content of black mica, a nearly massive habit, and rather large pink or reddish feldspars. It is a fairly acid or quartzose rock and shows marked powers of penetration and absorption in contact with the Grenville schists and gneisses. It intrudes and permeates practically all of the Grenville rocks except the limestone, wherein there are only occasional pegmatite dikes, and is much the most conspicuous individual element in the geology of large stretches of the area through its appearance in innumerable small bosses and networks of dikes and stringers that always stand out in the natural exposures on account of their fresh appearance and contrasting color. The map can give no adequate representation of the widespread development of the granite since the individual outcrops are usually too small to be indicated on it. In the aggregate these small offshoots bulk very large, so that the granite really is a greater factor in the geology of the district than appears from the areal map.

There can be no doubt that the porphyritic granite has played a considerable role as mineralizer; it has been indeed the most effective agent of all the igneous magmas in that capacity. Its powers of injection and assimilation are everywhere in evidence among the older schists and gneisses, and on contact with the limestones it has often effected a complete breaking up of the carbonates, with the formation of secondary silicates like diopside, tremolite, hornblende, phlogopite, tourmaline etc. That the solutions and vapors given off by the magma in the cooling process circulated for considerable distances from their source may be held as certain and it is to them no doubt that the veins and bodies of quartz and pegmatites which occur throughout all of the Grenville are to be referred, as well as the scattered occurrences of the silicate minerals in the limestone. Their agency in the formation of the zinc and pyrite deposits is not so clearly evidenced perhaps from field observations, but it is made fairly certain by studies of the mineral associations as will be brought out later in the description of these ores.

Most of the mineral occurrences of secondary type are the result of this igneous activity, although it does not necessarily follow that all of the chemical substances represented in their constitution were contributed by the granite. The solutions and vapors that were given off were powerful solvents, capable of attacking the existing mineral combinations in the rocks through which they circulated and setting up new ones more stable under the prevailing physical conditions. In some instances probably the changes have involved little in the way of new contributions, the solutions having collected the various materials during their progress within the country formations. Thus the common mineral impurities of the limestone are combinations of lime, magnesia and silica chiefly, which all may have been contributed by these rocks, which usually contain small amounts of silica, alumina, magnesia, iron etc., besides lime, in their normal development. There is some question as to the actual transference of material from the igneous magmas in the formation of silicates like tremolite, diopside, enstatite, phlogopite and others of their class, which occur within the calcareous beds. It seems likely, however, that at least much of the silica required for the formation of such compounds has been contributed by the igneous materials; the wide distribution of vitreous and massive white quartz, certainly to be traced to the granite quite as much as the pegmatite, is a noticeable feature and shows that the solutions carried large amounts of free silica available for combination with bases. For the more complex silicates, and particularly those containing such elements as fluorine, chlorine and boron as essential ingredients, it is even more necessary to assume the participation of magmatic materials.

The mineralization may be characterized in general as of contact type. Not always are the occurrences along the margin of the granite, as would be inferred perhaps from the use of the word "contact" in this connection, but they are nowhere very remote from bodies of that rock or its offshoots. The term is here used in the broad sense to indicate rather the process than the locus or position of mineral development. From the widespread occurrence of granite dikes and stringers and the manner in which the magma has drenched the older Grenville silicate rocks, it may be inferred that there are large bodies of granite below the surface — the present exposures representing only the upper outlying parts of the intrusion which mainly cooled and solidified deeper down in the earth.

Of all the rock formations, the Grenville beds, and especially the limestones, are most susceptible to the action of mineralizing agencies. This is owing partly to their physical character, incident to their jointed and bedded condition with the numerous openings thus provided for the admission and circulation of waters, and partly to their chemical nature which renders them more easily a prey to chemical reaction and solution. The limestones are particularly prone to chemical attack, whereas the schists and gneisses, composed largely of quartz and silicates, are more resistant to this influence.

Geology in Relation to Prospecting and Mining

For the location and preliminary field study of the mineral deposits of the district, the most valuable guide is the geological map which accompanies this report. Upon the nature of the rock formations depends primarily the character of the mineral deposits associated with them. This is a principle that applies very generally to mineralized areas. It is also a matter of observation that particular localities are closely related to certain special geological conditions, such as may be supplied by local variations in the rocks in regard to composition and structural features. Of first importance for the prospector, however, is the discrimination of the rock type, for which the geological map provides the general basis.

Broadly, the rocks of the Gouverneur area fall into two main groups, according to their method of origin, the one sedimentary and the other igneous. The first group comprises the Grenville series, and is made up of former sandstones, limestones, clays and silts, now represented by quartz schists, crystalline limestones and dolomite, and various gneisses of which the garnet-gneiss is a typical member. The sediments were probably formed in successive beds in an ancient sea, and they are properly grouped into a single series, the oldest of all in the district. The second or igneous group consists of the reddish porphyritic granite and its numerous pegmatitic offshoots, the fine-grained gneissic granite, and the gneissic gabbro or amphibolite. Wherever the igneous members are in contact with the sedimentary group, their relation is intrusive as far as the conditions can be determined at all.

In the preceding pages it was pointed out that the porphyritic granite has influenced the formation of certain mineral deposits. Its contribution would appear to have been two-fold: first, as the parent source of many quartz veins and pegmatites with their contained minerals, and second, as a mineralizing agent by virtue of the hot liquids and vapors that were given off by the magma in its cooling stages and that by reason of their heat and content of solvent substances, like fluorine, chlorine and sulphur dioxide, were able to take up and transport materials quite resistant to ordinary geological processes. The mineral-bearing waters and vapors circulated outward and upward from the invading magma, from regions of higher pressure and heat to those of moderate depth in which conditions may have approached those at the surface. In this circulation their solvent capacity would have diminished with distance from the granite magma; deposition of the mineral substances followed as a necessary consequence along the path of the circulations and in reverse order of their solubility. The sediments by reason of their open textures, their favorable structures, or their chemical nature, were more accessible to the movement of the mineral solutions than the igneous formations, generally speaking, and were the collecting ground for many of the deposits.

The bodies of pegmatite and quartz stand in the closest relation to the granite. In certain instances they are but a differential phase of the granite itself, occurring within or on the borders of the separate instrusions and showing more or less gradation from the one to the other material. Such included bodies have, therefore, a rather indefinite boundary. Dikes and small bosses of pegmatite also occur in all of the other formations and particularly those of the sedimentary or Grenville series; these, as a rule, have sharp boundaries against the inclosing rocks and the boundaries often appear to have been determined by lines of weakness in the latter as represented by bedding structures, joints or faults.

A different type of deposit that resulted from the granite invasions is represented by the silicate zones within the limestone belts, especially those limestones that are of magnesian character. Where the carbonate rocks occur in proximity to the granite, they are likely to contain silicate impurities, notably tremolite, diopside, enstatite and tourmaline. In places considerable bodies of limestone have been converted into a pure tremolite schist. Such silicate zones would appear to have been formed by a mingling of certain elements of the granite, particularly silica (also iron, boron and fluorine when present), with the bases, lime and magnesia, present in the limestones. They are contact-metamorphic deposits in the common classification of mineral deposits. An important economic product of this group is fibrous talc, which occurs in the Edwards-Sylvia lake limestone belt in intimate association with tremolite. Local alteration of the tremolite, accompanied by removal of lime and taking up of water, has produced talc, which often retains the physical characteristics of the tremolite.[1] By a similar process of change much of the diopside originally occurring in the limestone has been converted into serpentine.

The zinc-pyrite deposits of the Edwards district that quite recently have come into prominence for the production of zinc are traceable to the mineralizing influence of the granite exercised during a later stage of the cooling process than the contact-metamorphic deposits. They favor the outer borders of the limestone belt and the more important deposits thus far opened lie within zones of the country rock that contain abundant silicates. Some occur in close proximity to talc. Besides silicates and carbonates, the gangue contains small amounts of barite and more or less free quartz. Of considerable practical importance for the milling and smelting of the ores is the small content of lead minerals, galena

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[1] Smyth, C. H., jr. The Genesis of the Talc Deposits of St Lawrence County, N. Y. Sch. of Mines Quart., v. 17, 1896, p. 333–41.

being present in very minute proportions. As is explained in the section on the zinc deposits (page 90), the ores are in the nature of replacements of the wall rocks, the ore-bearing solutions having effected a chemical interchange between the carbonate minerals and the metallic sulphides. By this process of deposition no large openings were required to give room for the ore-bodies but the waters found their way along narrow fissures and joints, which they widened by solution of the carbonate minerals as they precipitated their content of sulphides. The ores are characterized by a close texture and uniformity of size of the metallic minerals, the individual particles being approximately of the same size as the minerals of the gangue. The ores were deposited at considerable depths and were later exposed in their present positions by erosion of the limestones. The most favorable ground for their occurrence, other things being equal, is along the edges of the limestone belt, within the first few hundred feet from the contact with the granite.

Pyrite, alone or associated with pyrrhotite, is found in workable bodies in the Grenville quartz schists and garnet-gneisses; its derivation probably has been somewhat analogous to the zinc-pyrite ores. The gneisses and schists that carry pyrite in abundance have a considerable admixture with granite. It is not demonstrable with certainty that the granite has contributed the iron for the production of all the pyrite — or the zinc for the preceding group of deposits — but its influence in stimulating and increasing the solvent effect of the circulations that accomplished the mineral concentration may at least be accepted as fairly established.

The relation between the larger features of the distribution of the mineral deposits on the one hand and the nature of the containing formations on the other needs hardly to be further emphasized. The hosts of practically all the valuable ores and minerals are the Grenville sediments. Pegmatites and quartz veins occur in the igneous country, but even they are rather more prominent in the Grenville as offshoots of the granite. Limestone is the distinctive country for talc and zinc; the sedimentary quartz-silicate rocks for pyrite, pyrrhotite and graphite.

If the conditions surrounding the concentration of the ores and minerals have been correctly interpreted, certain deductions that are of importance to the mining industry may be made as necessary sequence to those conditions. The concentration in general has been effected by hot ascending solutions having their sources at

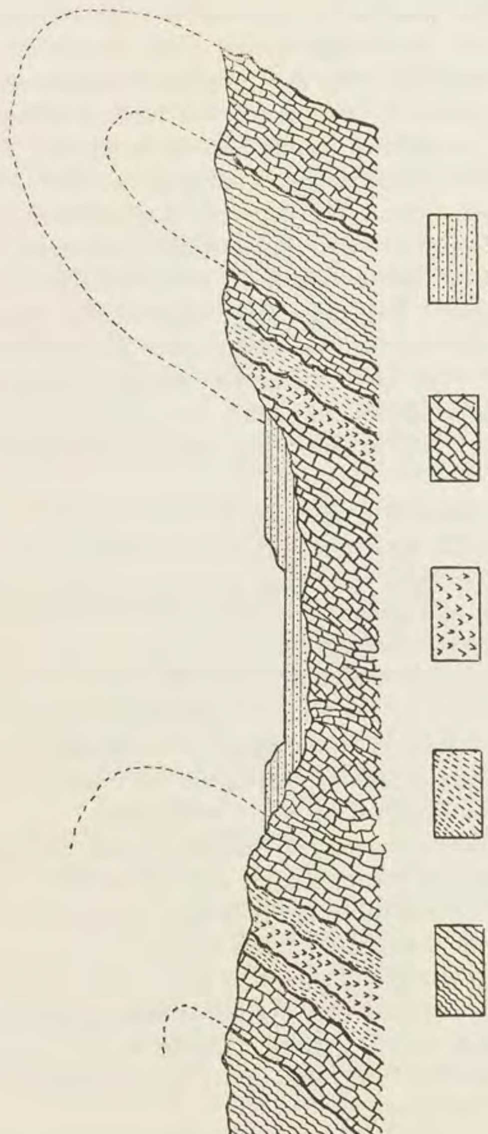


Figure 14 Section across the limestone belt at Edwards, showing folded relations of the Grenville strata. The central belt is a syncline, bordered by compressed anticlines.

considerable depths. As a consequence the deposits are not likely to be shallow in the sense of being limited to a restricted surface zone, characteristic for ore bodies formed by downward-moving surface waters. But in the case of the zinc and pyrite ores the mineralization is possibly coextensive downward with the depths attained by the folded schists and limestones or so far downward as these maintain the same characteristics physically and chemically as they have near the surface. This view, expressed by the writer in the period of the early mining operations at Edwards, has been confirmed in part by the results of exploration to depths of over 1000 feet. Another consequence of the method of origin is the uniformity in the content of the ores and their physical make-up irrespective of the depths from which they come. This also is not usually the case with concentrations by surface waters which are apt to show marked changes within rather limited ranges of depth. The absence of vugs, caves and open fissures in connection with the zinc ores is a further characteristic connected with their manner of origin and one that contributes to economy of mining and exploration.

In the study of the field structures of the ore bodies and the country formations, it is important to note that the period of general mineralization was in the early Precambrian, subsequent to which was a long period of erosion that terminated only with the opening of the Cambrian period and the deposition of the Potsdam sandstone. This prolonged erosion was deep enough to plane down the surface to a nearly uniform level, cutting away a great but undetermined thickness of rocks. The folded structures which are exemplified so well in the Grenville strata indicate that the region before planation must have been fairly elevated and mountainous, and it is probable that many thousands of feet of rock are represented in the eroded continuations of the folds indicated by the present attitudes of the rocks. Any superficial mineral deposits that existed previous to the erosion period were necessarily carried away and dissipated.

The Potsdam sandstone which is found here and there resting in nearly horizontal beds upon the Precambrian formations is but a remnant of what was once a thick cover of early Paleozoic strata that included various shale and limestone members as well as sandstone. It is only in recent times that the Precambrian surface has reappeared from under the mantle of the bedded strata. This period of burial was one of almost stagnant conditions for mineralization in the Precambrian within the Gouverneur area. There were no new deposits formed of any importance, and those already existing were little modified during the interval.

Consequently the occurrence of Potsdam has little or no bearing upon the existence of mineral deposits in the underlying Precambrian. There is the same likelihood of finding them under the sandstone as in the exposed formations, other things being equal.

List of Minerals and Mineral Localities

Preliminary to the description of the deposits of economic importance, brief mention will be made of the various minerals which have been noted as native to the district and of their local occurrence. The list of mineral species for the district embraces a large number that have no special value industrially, as in fact the useful minerals generally constitute only a small proportion of those actually known. The vicinity of Gouverneur has provided a great array of minerals in the way of crystallized and uncommon physical forms, and not a little that has served as type material for purposes of scientific description or illustration, so that an enumeration of the individual species with information of their occurrence may prove serviceable to the student and collector.

In the compilation of the mineral occurrences information has been drawn to some extent from published sources, notably Dana's Manual which is valuable principally for the data about the early discoveries, from the reports of the First Geological Survey of New York State and particularly those by Emmons and Beck, and from Whitlock's New York Mineral Localities.[1] The last-named work is the most complete in its references to the mineral occurrences of the district that has appeared up to the present time. The information thus made available has been supplemented by observations in the district by the writer in the course of a field experience that extends through a period of many years.

Although attention is restricted generally to those occurrences within the limits of the map, a few localities of particular interest that are found in the bordering areas will be included, for which Gouverneur would naturally be used as a base by any one intending to visit such places.

Actinolite. This variety of amphibole occurs in characteristic development of thin bladed and fibrous crystals in the walls of the talc mines in the town of Edwards. It has the same methods of occurrence as tremolite, the common parent mineral of the talc, and

[1] N. Y. State Mus. Bul. 70, 1903.

differs in appearance only in its greenish color which is traceable to the small content of iron in ferrous form. The crystals occur in felted or matted intergrowths, as actinolite schist. The country rock is limestone, but porphyritic granite appears nearby.

Albite. Soda feldspar is present in some of the pegmatite bodies, as one of the essential constituents. It is associated usually with microcline and may be intergrown with it as perthite. One of the localities where both varieties are found in large crystals or masses is at the quarry now being worked for pottery spar on the road between Richville station and East De Kalb, 3 miles northeast of the former place.

Amphibole. The members of this mineral family are mentioned under their specific names, as far as they are recognized. (*See* actinolite and tremolite.) Various aluminous amphiboles are represented, of which the exact composition and type has not been determined. One of the common forms is of greenish color in prismatic shapes, to be classed probably with the variety pargasite. It is found in the limestones, often associated with tremolite and diopside. Localities are the Calvin Mitchel farm in East De Kalb, the zinc mines at Edwards and the vicinity of Talcville. Darker green or black amphibole is an important ingredient of the gneisses; one of the gneissic rocks developed on the borders of the Edwards limestone belt consists largely of this mineral and is described in the first part of the report under the name "amphibolite." It is believed to be derived from gabbro, in which case the amphibole is probably derived from an aluminous pyroxene. Black or green amphibole is also an accompaniment of some of the Grenville schists.

Apatite. Crystals of apatite, greenish or reddish in color, small to fairly large in size, occur in the crystalline limestones, notably in the marble quarries north and south of Gouverneur. The quarries just southwest of the town have supplied examples of the usual six-sided prisms, terminated by the unit pyramid, 4 to 6 inches long. Beck[1] records a crystal nearly a foot long and weighing 18 pounds from the Robinson farm, town of Hammond, which is outside the limits of the map. This locality is perhaps the same as that listed by Whitlock as near DeLong's mills.

Asbestos. Fibrous tremolite, or brittle asbestos, is not uncommon in the walls of the talc mines, one or both of which may be constituted of tremolite schist. It is also to be seen in other limestone areas, as a development of the normal tremolite. The flexible

[1] Mineralogy of New York, 1842, p. 282.

asbestos, or chrysotile, is an occasional accompaniment of the massive serpentine disseminated through the Edwards limestone. The occurrences are of no commercial interest.

Barite. In the zinc ores of the Edwards district barite is generally present in the form of small crystals or grains intergrown with the calcite. In the ore-forming process it has been partly replaced by the sulphide minerals. The presence of barite is not easily detected in the examination of the ore although it shows readily on crushing and separation as practised at the mill of the Northern Ore Company, which reports the presence of 1 to 3 per cent of barite in the run-of-mine product. Large crystals are reported to occur at Osborn lake, in the western part of De Kalb township.

Biotite. This occurs widely in the granites, pegmatites and gneisses of the district as an essential component. Large plates are obtainable in the coarse-grained rocks. It has no commercial value for electrical purposes owing to the iron content and is too nearly opaque to be useful for stove mica.

Calcite. Although abundant in the limestones and marbles of the district, good crystallized specimens are not common. The noted localities, of which there are many in western St Lawrence county, are all off the Gouverneur sheet; the Rossie and Hammond lead mines which are reached in a short drive from Gouverneur, have provided great quantities of crystallized material, some clear and almost of optical grade. Descriptions of these will be found in Whitlock's Calcites of New York.[1]

Chalcopyrite. This is an occasional ingredient of the pyrite deposits, but never an important one.

Datolite. The only occurrence that has been noted is on the Calvin Mitchel farm, in the town of De Kalb, mentioned in the following paragraph. It is rather uncommon at that place.

Diopside. Green pyroxene belonging to the diopside species is prevalent as small disseminated crystals or aggregates in the limestones, particularly those of the Edwards district. It is the parent mineral of the serpentine, characteristic of much of the limestone, and in thin section is observed to occur as nuclear particles surrounded by serpentine.

Transparent, well-formed crystals of gem quality occur on the Calvin Mitchel place, 3 miles northeast of Richville Station, town of East De Kalb. The prismatic crystals measure as much as 2 or 3 inches in length by an inch across, with single terminations. They

[1] N. Y. State Museum Memoir 13, 1910.

occur along crevices in a quartz-banded limestone, associated with a green amphibole, and rarely with datolite. They were collected in quantity by Mr Mitchel and sold to mineral collectors and for gem cutting; the cut stones have a light green to grass green color and considerable brilliancy, almost that of peridote. Crystals from this locality are figured in Dana's Manual. They are unique in perfection and quality of color for New York State. A few crystals have also been obtained from the George Foster farm, 2 miles east of Richville station.

Dolomite. A subordinate ingredient of most of the crystalline limestones or marbles of the district, where it is intergrown with calcite and only distinguishable by chemical analysis of optical tests. The Gouverneur marble contains 10 per cent or so of the mineral and the Edwards limestone considerable more. The white marble near the Rock Island School, 3 miles north of Gouverneur, quarried for building stone, is practically pure dolomite, containing about 20 per cent of magnesia (21.7 per cent required by formula). This locality is given further mention in the section devoted to quarry materials.

Enstatite. This mineral is commonly recorded in the works on mineralogy as occurring with the talc of Edwards and Fowler, associated with tremolite. It is an uncommon mineral, however, in the writer's observation which extends to all of the principal talc mines. The only place where it has been found in quantity is a prospect one-half mile north of the Edwards zinc mine, which shows a small outcrop of enstatite schist, made up of an intergrowth of bladed crystals that have a bronzy appearance and are partially altered to talc. In general, tremolite is the ancestral source of the talc, not pyroxene.

Fluorite. This is rather rare for this district, but common in the Rossie and Macomb lead mines, and in one or two places occurs separately in masses or crystal aggregates in the limestone. The town of Macomb has yielded some fine exhibit specimens of bright green fluorite, of which a large quantity (15 tons) came from a locality discovered in 1889, and showed cubes of the mineral up to a foot across. Examples of this occurrence are in the State Museum at Albany. In the Gouverneur section it is a minor constituent of some pegmatites.

Galena. The zinc ores of the Edwards district contain a small proportion of lead sulphide or galena in mechanical admixture with the pyrite and blende. At the Edwards mine itself, it is only occasionally present in visible form, but specimens from the Williams shaft on the northern end not uncommonly afford cleavages of the mineral that measure up to an inch across. That it is a component of all of the ore to the extent of a fraction of a per cent is evidenced in the mill treatment, for a band of the gray galena invariably appears on the concentrating table above the sphalerite. On the Balmat farm in the southwestern part of the district there is a vein in which galena constitutes an important ingredient and which once was worked for this mineral, rather than for zinc. This occurrence is reported to carry a little silver.

The principal occurrences of galena in St Lawrence county are a few miles out of Gouverneur and off the limits of the map, in the towns of Rossie and Macomb. They consist of fissure veins, from a few inches to 2 or 3 feet wide, intersecting the Precambrian gneisses and crystalline limestone and in one or two places they extend upward into the Potsdam sandstone. The gangue consists of calcite with some fluorite and barite, while chalcopyrite, sphalerite and pyrite constitute with galena the metallic ingredients. From the vugs and cavities in the veins have come beautifully crystallized examples of these different minerals, which are scarcely obtainable at present owing to the caving and filling of the shafts. The Coal hill vein near Rossie village is said to have produced 1625 tons of lead in the early period of mine operations which started about 1836 and lasted for about 15 years. The Victoria or Pardee mine, in the same vicinity, also was worked quite extensively, the vein having been followed to a depth of 300 feet and a mill and smelter having been erected for treating the output. In the town of Macomb galena occurs at Mineral Point on Black lake, an old mining locality, also on the farm of F. E. Turner, 3 miles north of Brasie Corners, and on the Downing, Pennock, and Jones places near Pierces Corners. The small size of the veins precludes their practical operation for lead at the present time; but their relative content of galena may be fairly high.

Garnet. Garnet is common in the Grenville gneisses and on granite contacts. It is a constant ingredient of one member of the Grenville, a garnet-gneiss that occurs in the southeastern part of the quadrangle, north and south of Edwards village, the garnet being distributed in small crystals and roundish particles of pink color in a mixture of feldspar, quartz and mica. Occasionally the garnet attains half an inch in diameter, but usually is much smaller. The development of garnet as a reaction mineral in the vicinity of granite and pegmatite is a widespread phenomenon and it is hardly necessary to refer to separate localities.

A band of very rich garnet rock, about 2 miles north of Gouverneur on the road to Peabody bridge, has been the object of some mining activity. About 1902 the Gouverneur Garnet and Lead Mining Company started operations in the locality with the purpose of producing garnet for abrasive uses. The garnet is of pinkish color and probably almandite; it occurs in round particles that average not over one-quarter of an inch diameter but are very plentifully distributed so as to constitute fully one-fourth of the entire rock mass. The other ingredients are bright green and the combination of color makes the rock a striking one when seen in fresh specimens. It is no doubt a development of the Grenville gneisses and resembles very much one of the Grenville rocks commonly associated with the graphite beds of the eastern Adirondacks. The rock is richer in garnet than that available in most places for quarrying, but the mineral is rather too fine to serve the purpose of an abrasive, after it has been submitted to the necessary reduction required for its separation. The quarry has not been worked for a number of years.

Graphite. This mineral is quite common in the sedimentary schists of the Grenville series, in which it is disseminated in small scales or flakes through the body of the schists, constituting perhaps 2 or 3 per cent of the mass. The schist belts of the Edwards-Sylvia lake district and of the Gouverneur pyrite belt exemplify this method of occurrence. It is also occasionally to be seen in the crystalline limestones or marbles. So far as is known, there are no deposits within the quadrangle that seem to merit attention from an economic standpoint; only one or two graphite deposits in St Lawrence county have been worked to any extent, the principal operations centering on an occurrence of graphite schist near Popes Mills, town of Hammond, which yields a crystalline product of finer grain than the eastern Adirondack graphite. The product from this mine has been sold for paint purposes.

Greenockite. The zinc ores from the Edwards district have been observed in a few instances to have a coating of a greenish-yellow earthy substance that reacts for cadmium and has been identified as the sulphide greenockite. It is found on the weathered joint surfaces as a bloom, the result doubtless of partial decomposition of the sphalerite which itself contains little more than a trace of cadmium. The presence of the mineral was first observed by the writer in the ores from the mine of the Northern Ore Company. Good specimens were later collected from the Rhodes property near Talcville. No other occurrences of this mineral seem to have been recorded in the State.

Hematite. Deposits of red hematite are associated with the Grenville schists and limestones and have been the object of mining in years past. In some instances they are simply the gossan or weathered outcrop of the pyrite and pyrite-sphalerite ores; this seems to be true of the ore localities in the vicinity of Fullerville and Sylvia lake which once were worked for the supply of the Fullerville furnace. About a mile east of Fullerville, in the sand terrace which here is underlain by limestone, is an old shaft that has afforded some soft earthy and hard hematite, with more or less white quartz admixed with it. Another locality is the zinc prospect on the Dominion Company's property, just east of Sylvia lake. A soft earthy hematite was mined here some 30 years ago, the principal opening being a pit on the outcrop of a lens or shoot of the ore which in depth became charged with the sulphides of iron and zinc and thus unsuitable for smelting. Later exploration showed that the change progressed with depth, so that practically unaltered sulphides were taken in the prospect shaft at a depth of 100 feet or a little more. The occurrence of hematite within the limestone belt, may serve to indicate the presence of sulphides.

Other deposits of hematite occur in the Grenville schists, as at Ore Bed school, in the southern part of DeKalb township, and near Fowler. The schists in which it is found are pyritic, but the ore itself is free of sulphur and not apparently directly related to the pyrite. The occurrences are of little economic importance in themselves, although they illustrate a type which has played a considerable rôle in the iron industry of this section. The mines of the Antwerp district are found in association with pyritic Grenville schists and along the contact of the schists and crystalline limestone, the ore being a replacement of these rocks formed through the agency of underground circulations. The principal mines are situated along a belt that begins just north of Antwerp village and extends northeast, parallel with the R. W. & O. railroad, to near the Rossie-Gouverneur town line; they include the Dickson, Old Sterling, Morgan, Keene, Caledonia and Clarke mines, from which altogether a large quantity of ore has been mined.

Limonite. Bog iron ore abounds in many parts of St Lawrence county, where the sluggish streams and swampy areas favor its accumulation. The towns of Gouverneur, Fowler, Canton, and Brasher have yielded furnace material in some quantity during the time when local smelting operations were in progress 40 or 50 years ago. Limonite of spongy nature occurs as gossan on the outcrops of some of the zinc deposits of Edwards, notably the White property of the Northern Ore Company.

Magnetite. This mineral is an ingredient of the crystalline silicate rocks, particularly the granite and schists, but it is not known to occur in workable amount anywhere in the quadrangle. The large deposits of Benson Mines are off the limits of the map to the southeast of Edwards.

Microcline. This is an important mineral in the porphyritic granite and its pegmatite offshots. It is often intergrown with albite in perthitic arrangement, and is the principal feldspar in the quarries near Bigelow, which are described separately in this report.

Muscovite. Although this occurs in granite and to a minor extent in the pegmatites, it is not of economic importance.

Oligoclase. Occurrences of this mineral are noted in association with some of the granite and pegmatite, in the same manner as microcline, but in smaller amounts.

Pyrolusite. Good speciments of fernlike crystals of pyrolusite are found as an incrustation of the talc schist in the Edwards district. No. 2½ mine, Talcville, yields abundant specimens.

Pyrite. The occurrence of this important mineral is described separately. It is widespread in certain quartz schists of the Grenville.

Phlogopite. This occurs in small scaly crystals rather commonly in the limestone of Gouverneur and other sections, and, in larger sheets as a contact mineral associated with other secondary silicates like amphibole, wernerite, diopside and titanite. Sheets measuring 6 inches or more across were observed by the writer on the waste dumps of No. 2½ talc mine at Talcville.

Pyrrhotite. This accompanies pyrite in some of the deposits found in the Grenville schists. It is more particularly abundant in the deposits outside of the Gouverneur quadrangle and notably those at Pyrites, south of Canton, and at the Laidlaw prospects, near Oxbow, southwest of Gouverneur. It may carry a little nickel.

Quartz. Various forms occur in great abundance. It is found crystallized in vugs and fissures, and particularly in the Grenville quartz schists which constitute the wall rocks of the pyrite deposits. Handsome crystals have been taken from the mines of the St Lawrence Pyrites Company at Stellaville, near Hermon, just off the Gouverneur sheet. The crystals are simple combinations of the unit prism and pyramid. Massive quartz, white or vitreous, occurs very widely in veins that intersect all of the rocks and are most common around the borders of the porphyritic granite. The quartz has the characters of magmatic quartz; it appears in practically pure bodies and in combination with feldspar as pegmatites of varied composition. The occurrence of quartz in the Grenville limestone where it produces banded and ribbed structures is described in the earlier part of this report. The limestone on the borders of Sylvia lake especially abounds in quartz which stands out as white hummocks and reefs above the surface.

Chert and jasper are occasionally in evidence around the zinc deposits of the Edwards district. A considerable body of chert occurs on the limestone ridge that is mined by the Northern Ore Company, just north of Edwards.

Serpentine. This mineral abounds in the Edwards limestone belt as nodules and bunches enclosed by the carbonates. Most of the serpentine, as shown by Smyth,[1] is pseudomorphic after diopside, whereas talc, the other important secondary mineral in the limestone, is derived from tremolite. A peculiar whitish serpentine, seemingly of low iron content, is found in a quarry in the limestone area near Peabody bridge, north of Gouverneur. According to local accounts, the mineral was thought to be talc and some of it was ground and sold for the same purposes for which talc is employed. It is noticeably harder than talc and has rather an oily luster.

Sphalerite. Occurrences are noted in the lead veins of Rossie and Macomb as an accompaniment of galena, pyrite and chalcopyrite. In the Edwards district it is associated with pyrite and occurs in replacement bodies in the Grenville limestones. These are described elsewhere under their own title.

Talc. One of the important economic minerals of the Gouverneur district is talc. It is reserved for special description.

Titanite. Fair-sized recognizable crystals of titanite are found in some of the limestone-granite contacts, as near the Gouverneur marble quarries south of the village and in the vicinity of No. 2½ talc mine, Talcville. It is associated with diopside, tremolite, wernerite and tourmaline.

Tourmaline. This is quite common in white, brown and black crystals, as a sporadic ingredient of the limestones where it has been

[1] Genesis of the Zinc Ores of the Edwards District, St Lawrence County, N. Y. N. Y. State Mus. Bul. 201, 1918, p. 17–18.

formed by contact action with the porphyritic granite. Perhaps the best known occurrence of this type, from which have come most of the museum specimens that bear the locality name Gouverneur, is on the Reese farm, 2 miles southwest of Richville, on the Rock Island School road. It is described in some detail by Cushing on page 20. Good crystals of brown color are also to be had from the Rylestone marble quarry, southwest of Gouverneur. The black variety is a common accompaniment of the pegmatite bodies, all over the district, so widely scattered that specific mention of the localities seems unnecessary. As a constituent of the Grenville gneisses it occurs in various colors and locally may form 50 per cent of the entire rock mass. (See page 24.)

Tremolite. This member of the amphibole group is abundantly developed along the borders of some limestone areas, particularly the Edwards-Sylvia lake belt where great bodies of nearly pure tremolite in the form of crystalline aggregates appear along the contact and for some distance toward the interior of the belt. It is usually white in color and developed in long blades or needles without crystal terminations. The crystals are so interlaced that they make a very tough rock, although in the mass the latter appears to be of schistose structure. Bands of the tremolite may be traced for long distances parallel with the strike of the limestone. All of the talc mines are situated along these bands, with the tremolite forming one or both walls of the deposit.

The pink or purplish form of tremolite, called hexagonite, is a handsome mineral which occurs in the walls of the mines at Talcville, particularly on the southwestern end, and in the mines near Sylvia lake. Large masses of it are still available in the rock dumps of the old United States Talc Company's mine.

Vesuvianite. The only locality so far recorded for this mineral within the map limits, is 1 mile south of Gouverneur, probably one of the marble quarries. The locality is mentioned by Whitlock.[1]

Wad. This mineral is found in association with bog limonite in some of the Edwards and Gouverneur occurrences.

Wernerite. Sporadic occurrences of wernerite as a contact mineral are reported in the Grenville limestones. It is observed at Talcville and in the Gouverneur marble quarries.

[1] New York Mineral Localities. N. Y. State Mus. Bul. 70, 1903, p. 78.

DESCRIPTION OF IMPORTANT MINERAL DEPOSITS

Zinc Ore

Sphalerite occurs in commercial quantity in the vicinity of Edwards, Talcville, Sylvia lake and at other places within the limestone belt that stretches across the southeastern corner of the Gouverneur quandrangle. Its distribution broadly conforms with that of the talc which particularly favors the bordering zone of the limestones next to the granite and amphibolite that limit the limestone on the north and south sides.

Mining of zinc in this district began in the spring of 1915 and has been in continuous progress since then. The principal operations have been carried on by the Northern Ore Company whose mines and mills are situated just outside of the village of Edwards on the Trout lake road. This property was first prospected and developed by T. M. Williams, who about 1903 was in charge of iron mining operations in the Antwerp district and had his attention called to the uncovering of zinc ore on the Todd farm, a part of the properties taken over later by the Northern Ore Company. Mr Williams visited the place and recognized the possible importance of the occurrence. In association with the Northern Ore Company, he undertook systematic prospecting work which was continued for a year or more until operations were suspended on account of legal entanglements that were not dissolved until about 1910. The development of the deposits was then resumed, but it was not until 5 years later that mining began in a systematic manner, after various trials with processes for the separation of the sphalerite and pyrite.

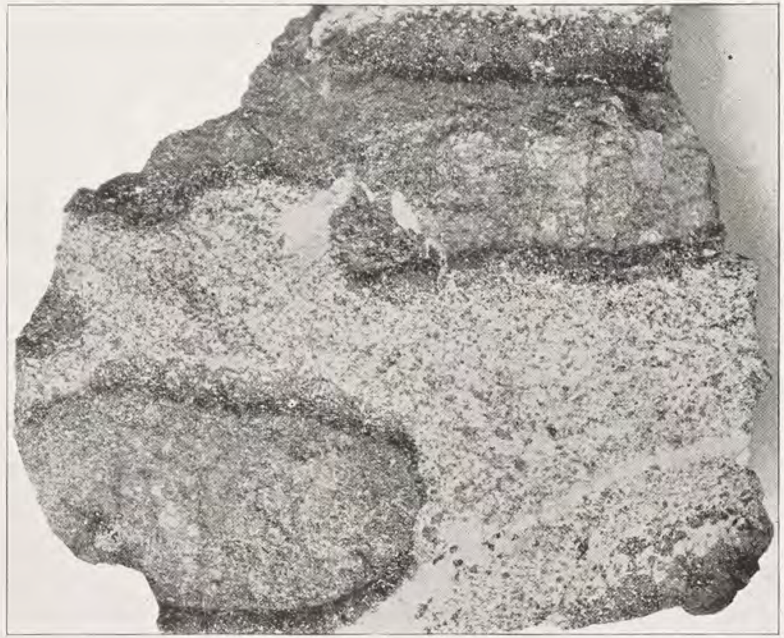
The Edwards deposits are only a part of the series of ore bodies which occur in the limestone between that place and Sylvia lake. They are the single active producers, however, out of the total of a dozen or more of occurrences, that have been discovered up to the present time. No doubt, others will be brought into operation in time and there seems to be every prospect that the district will continue for many years to contribute an important quota to the mineral output of the western Adirondacks.

Although zinc mining is relatively a new industry for this region the presence of sphalerite has been known for a long time, in fact since about 1835. In the reports of the First Geological Survey of New York, Ebenezer Emmons mentions the Balmat farm (wrongly

Plate 13

Folding and banding of impure Grenville limestone, Edwards.

Plate 14



Nodules of talc with serpentine rims in the ore-bearing limestone. Smaller grains of serpentine disseminated throughout the rock which carries sulphides so as to form a lean ore.

called Belmont) in the vicinity of Sylvia lake, as a locality for sphalerite and galena. At that time zinc was of limited importance as a metal and the ore did not warrant mining for lead alone.

The ores of the Edwards district do not seem to conform to any particular geological horizon in the Grenville limestone, but are associated more especially with those beds of the limestone that contain large amounts of silicate minerals and other impurities. The presence of tremolite and diopside and their alteration products, serpentine and talc, as well as vitreous and cherty quartz, is generally to be noted in the vicinity of the deposits. There is thus more or less close relation physically between the distribution of the talc and the zinc ores, both occurring in the impure beds that usually characterize the bordering zone of the limestone belt.

The ore bodies show much variety in their form and structure. On the surface the ore appears as bands or stripes set off more or less sharply from the wall rock, and again as indefinite patches of sulphides which become richer toward the middle and may grade into more or less solid bodies of the metallic compounds. Not infrequently the locus of ore deposition seems to have been determined by a fissure or crack within the limestone, as the ore may be seen to follow such opening more or less consistently and to be bounded by parallel walls. Underground the bands may appear to have the regularity of veins, but in a large way the ore pinches and swells and winds around quite without rule. In the mines at Edwards and Hyatt which are the only ones which have been opened to any considerable depth, the bodies may be described as lenses and shoots of ore, modified by rolls and pinches that evidently have resulted from compression subsequent to the ore deposition. In the mining of the ore it is frequently noticed that one of the walls is smooth, and free of inclusions of sulphides, while on the other side stringers and wisps of ore make off into the limestone for some distance, or may surround blocks of the limestone so that the contact on that side is quite irregular. On the free side a selvage of clay and talcy decomposition products may intervene between the country rock and ore, and this often serves as a water channel.

The ore is of compact, even-grained texture, with few openings or vugs, such as are found in ores occurring in open fissures deposited under surface conditions. Physically, it resembles the limestone in so much as the sulphides have about the same grain as the carbonates and the silicates appear in the ores much as they do in the unmodified limestone. The sphalerite is accompanied by more or less pyrite and the particles of both are approximately of the same average size, appearing in rounded or subangular grains, never as well-rounded crystals. The grain is apt to be somewhat coarser in the high-grade ores such as are exemplified by the well-defined bands or lenses, than it is in the disseminated leaner ores in which the sulphides are scattered through a ground-mass of carbonates. Samples of rich blende show individual cleavage surfaces an inch or so across, but in the average the diameter is not much more than one-fourth of an inch.

The sphalerite commonly belongs to the iron bearing variety and has a dark brown to black color. It is the typical black jack of the western mines. An analysis of a picked sample of sphalerite from the Northern Ore Company's mine, made in the laboratory of that company, gave the following results for the chief constituents: zinc, 60.61 per cent; iron, 4.91 per cent; sulphur, 32.73 per cent; Sum 98.25 per cent. This corresponds to 90.30 per cent zinc sulphide molecule and 7.73 per cent ferrous sulphide molecule, reckoning all of the iron in that form, with 0.2 per cent sulphur in excess. It is probable that some of the iron should be calculated in terms of pyrite rather than the monosulphide, but a small excess of sulphur is demanded no doubt in combination with lead and other metallic substances. It would appear that the blende normally carries 4 or 5 per cent of metallic iron.

Analyses of the zinc ores, representing the average product of the Northern Ore Company's mines for periods of a month each, are presented in columns 1 and 2, below. An analysis of a picked sample of the richer ore is given in column 3. The first two analyses are from the company's laboratories at Edwards, and number 3 has been made by R. W. Jones in the State Museum laboratory.

	1	*2*	*3*
SiO_2	21.47	18.52	5.69
Al_2O_3	4.17	12.12	.36
CaO	9.34	11.76	1.45
MgO	13.17	15.04	.61
BaO	[a] 2.75	[a] 1.52	1.46
CO_2	n. d.	n. d.	n. d.
H_2O	n. d.	n. d.	n. d.
Zn	21.47	18.52	51.43
Fe	8.50	8.46	5.80
Pb	.125	.197	tr.
S	19.006	17.18	30.86

[a] $BaSO_4$

Northern Ore Company's mine, Edwards. The ore bodies which have given the largest output up to the present time are situated within the low ridge of limestone that forms the first rise of ground just north of Edwards village across the alluvial flat or flood-plain of the Oswegatchie river. The limestone ridge is an isolated hill that lies in an embayment of Grenville gneiss. It is some 1200 feet long in a northeast-southwest direction and has a well-rounded oval contour, rising 40 or 50 feet above the general level.

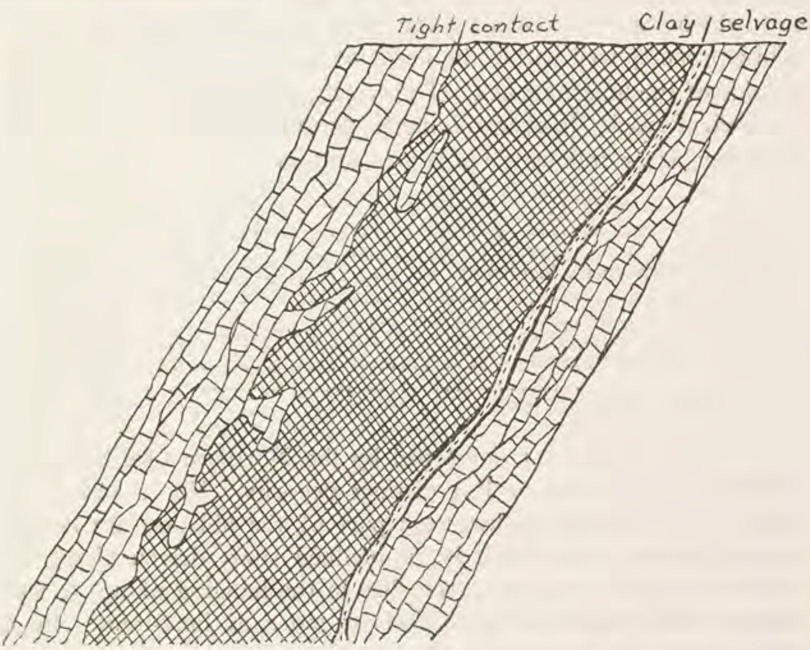


Figure 15 Relation of ore and limestone in No. 1 mine, Northern Ore Company.

On all sides except toward the southeast the limestone is bordered by gneiss, the latter rock belonging to a narrow band scarcely more than a few hundred feet wide that parallels the northern contact of the main limestone belt for several miles. Between this gneiss and the main granite border is an interval of a quarter of a mile wide that is occupied by a band of limestone similar to that of the main belt.

The relation of the gneiss and limestone seems to be that of an interbedded series. The gneiss is a dark hornblende-biotite variety sometimes carrying graphite, and in the immediate vicinity of the mines it contains a large amount of granitic material owing to the injection and diffusion of magmatic juice from the red granite which occurs in great abundance on the borders of the limestone areas. Over considerable areas the gneiss has been practically converted into granite, the original minerals of the gneiss having been thoroughly blended with those of the igneous rock. Layers of quartzite and small bands of limestone are occasionally intercalated with the gneiss. An insight into the relations of the gneiss and limestone along the contact is afforded by the log of a diamond drill hole which was put down by the Northern Ore Company on the White property well within the limits of the gneiss and on the hanging side of the limestone belt. The section in this hole as interpreted by Cecil Pocock, former mining engineer of the Northern Ore Company, is as follows from top to bottom:

Rock	*Feet*
Gneiss	0–153
Granite	153–170
Granite with gneiss inclusions	170–233
Limestone	233–325
Quartzite	325–342
Granite with some gneiss	342–473
Limestone and quartzite	473–566
Gneiss	566–715
Limestone and minor beds of quartzite	715–935

The ore bodies so far developed by the Northern Ore Company embrace several more or less distinct deposits. No. 1 and no. 2 veins outcrop in the southwestern part of the hill and are tapped by the Brown shaft which is an inclined shaft driven along the course of no. 1 vein. No. 2 vein lies in the hanging of no. 1, separated from the latter by 50 feet or more of limestone. No. 3 vein is about 600 feet northeast of no. 1 and no. 2 veins, close to the Trout lake road. It has been explored by the Williams shaft, but is worked through the fourth level of the Brown shaft by a 600-foot connection that follows the general strike of the limestone, all of the ore being hoisted through the Brown shaft. No. 0 vein lies in the southwestern part of the area on the hanging side of no. 2 vein, and is not exposed at the surface. It was first encountered in the vertical shaft which was put down after the other shafts to tap the lower workings of the Brown mine. The vein was cut on the 900-foot level and has been followed upward by raises from that level.

In shape no. 1 and no. 2 veins may be described as broad, thin lenses, which in their limited outcrops appear as bands with parallel walls. They show well-marked boundaries against the limestone on the foot and hanging sides, like fissure fillings or veins, but against this interpretation of their character may be cited the evidence of replacement that is found all through the ore and the fact that there is no continuous selvage or parting plane along either wall. Both bodies are warped out of plane, no. 1 being arched toward the hanging side in a broad semicircular curve, and no. 2 warped to a less extent. They vary greatly in thickness in depth and on the strike. On the outcrop no. 1 was about 4 feet thick and no. 2 a little less. In depth they swell up to 12 or 14 feet in rolls, but these are succeeded by pinches which constrict the ore to a foot or less in thickness.

The White or no. 3 ore body is not so well defined on the surface as the others; its outcrop consists of a zone of limestone 15 to 20 feet thick that carries bunches and disseminations of sulphides intermixed with much serpentine. The ore is distinctly brecciated in places. In depth the deposit develops the form of a shoot which may be the result of a thickening of a lens by folding or lateral compression. The underground drift between the Brown and White workings provide a good exposure of the limestone beds which at the surface are considerably weathered, and only on view in a few places. There appears to be no structural break of any importance in the interval.

No. 0 vein which was first encountered in the sinking of the new vertical shaft, is only about 25 feet wide and 4 feet thick on the 900-foot level. It has a dip of about 25 degrees at the bottom but this increases to 60 degrees on the 800-foot level where the ore widens to 160 feet and averages fully 20 feet thick. The ore, like all the rest in these deposits, carries considerable pyrite, but this mineral is much more abundant on the foot and hanging sides than in the center of the vein.

The ore of these deposits is characterized by an almost complete replacement of the carbonate minerals so that the grade averages high. Still the tenor of zinc fluctuates considerable with the varying proportions of pyrite and other ingredients. The actual average of the run-of-mine may be taken at 18 to 20 per cent zinc, according to the mill sampling for monthly periods. This indicates a sphalerite content of 25 per cent or slightly more after allowance for combined iron.

Galena seldom appears in visible particles but is present in all the ores to the extent of a fraction of 1 per cent at least. Its general presence becomes evident during the process of mill treatment, for a small band of gray galena always appears on the concentrating tables just above the brown sphalerite. At the Williams shaft on the north side, specimens were picked up which showed cleavage faces of galena an inch or so across, surrounded by sphalerite. These may be the result of secondary deposition. Barite occurs in small amounts although it can seldom be identified by the unaided eye. Tests indicate that it constitutes from 1 to 3 per cent of the ore. The other accompaniments of the ore are quartz, tremolite, diopside, serpentine and talc, all of which occur more or less abundantly in the country limestone.

Webb farm south of Edwards. To the south of Edwards, the first showings of ore are found on the Woodcock, Webb and McGill places, situated on the Fullerville road. The deposits lie along the southern margin of the limestone belt, across the valley from the Northern Ore Company's mine, from which they are about 2 miles distant in a straight line. The existence of zinc in this vicinity was first brought to notice by A. J. Moore, formerly of Edwards, who did some prospecting there in 1914. More recently the Lux Development Company has been engaged in exploring the outcrops on the Webb place.

The ore in this section occurs along a restricted zone within the limestone, following the strike of the beds and keeping close to their contact with the gneiss. The latter is a gray, garnetiferous often rusty rock that is banded and injected by granite. It belongs to the Grenville series and here lies below the limestone, both rocks having a northerly dip at a high angle. The peculiar relations which characterize the contact in this vicinity have been noted in the discussion of the structure of the limestone belt.

The ore is found as disseminations and richer bunches, which show no sharply defined boundaries toward the country rock, but rather grade off on the edges. The sphalerite may be scattered through a band of limestone 6 to 8 feet wide, but in a very uneven way. Altogether the outcrops and prospect holes — none more than a few feet deep — occur over a distance of 800 feet along the edge of a ravine which has been eroded in the limestone on a northeasterly course.

The sphalerite is lighter in color than the ore of the Edwards mine of the Northern Ore Company, but it contains more or less iron. It is admixed with pyrite, so as to form a granular mixture of rather fine texture; occasionally pieces of coarse blende nearly free from pyrite occur, as at Edwards. In all the ore there is considerable gangue stuff in the form of serpentine and talc nodules and unreplaced carbonates. There is so much variation that it is difficult to estimate the average tenor.

The exploratory operations have been confined to the sinking of shallow pits or shafts in three or four places. While much of the ore is of commercial grade in regard to zinc content, the quantity so far revealed is hardly sufficient to afford a basis for mining.

McGill farm. This adjoins the Webb place on the northeast, lying along the same ridge of limestone, close to the gneiss. The occurrence of ore is manifested in outcrop at a distance of 1000 feet or more from the most northerly opening on the Webb place. At the time of the writer's visit, in the fall of 1916, little had been done to prospect the deposit. The sphalerite is found as a dissemination within a layer of the limestone some 4 or 5 feet wide and of uncertain extent on the strike. There is little admixture of pyrite and the ore has a light brown color, significant of a minimum of combined iron. The dip of the ore band seems to be about 30° northwest. There is much serpentine in evidence and on the hanging side a little slip-fiber asbestos.

Woodcock farm. Continuing along the gneiss contact scattered occurrences of sulphides may be seen or are indicated by the rusty honeycombed appearance of the limestone. Two or three exposures have been made by blasting in which 6 to 8 feet of limestone more or less charged with ore has been uncovered. The gneiss lies scarcely 50 feet away. The limestone beds in this locality are ribbed by narrow bands of white vitreous quartz, so prominent in the Sylvia lake region. The occurrences stretch over a distance of 300 feet or more.

Balmat place. This lies just north of Balmat Corners on the Fowler road and one-half mile east of Sylvia lake. It is probably the first property in the district to have been prospected, as there is mention of the exploration of one of the bodies which it contains in the report by E. Emmons relating to the First Geological Survey in 1838. Emmons refers to the property under the name of Belmont and from his description it is evident that the object of the early search was lead rather than zinc, the latter metal being of little use in those days. The separation of the mixture of zinc, galena and pyrite proved too much of a problem for the success of the operations.

The results of the early exploration are to be seen in a shaft which was sunk on the more northerly deposit near the road, which is but a little distance from the Arnold talc mine. The depth of the shaft is uncertain, it being now partly filled with water, but is probably not over 75 feet. On the side hill below the outcrop a tunnel has been driven into the hanging so as to give access to the shaft workings and partly drain them. This may have been excavated at a later date than the exploratory work described by Emmons, but there seems to be no record of the time or of those interested in the renewal of operations. The body that is explored by the shaft outcrops at the surface to the southwest as a rusty band in limestones, ranging from a few inches to several feet thick. It can be traced for quite a distance in that direction. Underground it shows the same variation in thickness.

Some of the ore from the early operations was still to be seen recently about the shaft. In its content of galena which is fairly abundant in much of the material, it differs from the rest of the ores in the Edwards district. T. M. Williams, who was able to inspect the workings in some detail, states that the lead-bearing ore occurs only as a local phase, really as a distinct body from the main sphalerite deposit. In this event it may well be a separate ore concentration formed under different conditions and at a different time, possibly analagous to the lead ores to the north of Gouverneur. It was the galena that was sought by the early prospectors.

The zinc ore from this locality is distinguished by a prevailingly fine granular, dark metallic sphalerite which forms a groundmass for numerous larger grains of pyrite. The sphalerite particles are usually measurable by a few hundredths of an inch, while the average diameter of the pyrite is perhaps one-fourth of an inch. The ore from the more or less weathered outcrop has a loose, somewhat crumbly texture.

A secondary exploratory shaft has been put down on the Balmat property about 1000 feet to the south and east of the first, on what is apparently a parallel body on the footwall side. Little information about this occurrence could be gained at the time of the writer's visit, the workings having become inaccessible by caving.

Streeter place. On the trend of the more easterly Balmat deposit and across the Fowler road occurs a well-defined band of ore which can be traced for some distance along its northeasterly course. Its outcrop is on the northerly side of a low ridge of limestone, next to a small swamp under which the ore extends on the dip with a higher bluff of limestone on the opposite side of the swamp. The tract is a part of the Streeter place, according to J. H. McLear of Gouverneur, to whom the writer is indebted for many facts in regard to the property ownership in this section.

The limestone and the ore outcrop are covered with soil and drift, except here and there, so that the full extent of the deposit and its relation if any to the Balmat leads are not certain, but it appears to be of substantial character. It has been explored in three places by shallow pits, of which the central one is the largest and deepest. Apparently the exploration was performed many years ago, and may be contemporary with the early work on the Balmat, although there is no mention of the Streeter property in the reports of the first survey which refer to the adjacent deposits.

The ore is 6 to 8 feet thick in the face exposed in the central pit, while the hanging wall is more or less charged with sulphides for a couple of feet more. The dip seems to be about 30° northwest, but there is some uncertainty in regard to the matter owing to the small extent of the exposure. The limestone in the vicinity shows contortion, so that its attitude is subject to quick changes of dip and strike; the general trend, however, is nearly northeast and the dip 30–45° northwest. The same admixture of serpentine and talc characterizes the beds as has been noted for many of the other ore-bearing localities. On the hanging side of the ore, less than one-fourth of a mile distant, is a zone of fibrous and foliated talc that has been mined for many years.

The ore has much the same appearance as that on the Balmat place, but there is no galena to be seen from microscopic examination. The blende is of dark color and metallic lustre. In texture it is finely granular, the particles averaging between one and two-tenths of an inch in diameter. The associated pyrite occurs in two forms: in part as minute particles of generally cubic habit, sometimes showing distinct crystal boundaries, and in part as coarse irregularly bounded masses which may be seen to enclose occasional sphalerite grains. The latter are perhaps secondary growths. All of the ore contains unreplaced carbonates which are usually apparent to the eye.

No prospecting has been done on the deposit in recent years, although it must be considered as one of the more promising occurrences in the district. The lack of attention may be ascribed to the difficulty — not uncommon in St Lawrence county — of securing title to the mineral rights on the property owing to their divided ownership. There is some hope, I understand, that this impediment will soon be overcome.

Dominion Company's property, Sylvia lake. On the west side of the Fowler road, within a short distance of Sylvia lake, is a deposit of zinc ore owned by the Dominion Company of Gouverneur. The property lies along the branch road that turns off from the main road to the southwest, as indicated by the dotted line on the topographic maps. It is a part of the original Balmat estate, according to J. H. McLear of the Dominion Company, but represents a separate interest as to mineral rights from the Balmat mine already described. The deposits, also, belongs to a distinct ore zone, lying to the northwest of the Balmat-Streeter zone, and farther within the limestone area.

The principal opening on the property consists of a shaft put down on the side of a former pit from which iron ore was mined some 30 years or more ago for the Fullerville furnace now dismantled. The presence of zinc was suspected by reason of the pyrite that appeared in the material from the bottom of the pit at about 25 feet depth. Some samples of this ore were examined by the writer who confirmed the existence of sphalerite in a finely divided condition, along with pyrite, in a mass otherwise composed of iron oxides and vein quartz. The extreme fineness of the grain and the plentiful admixture of vitreous quartz distinguish the ore from this locality from the other occurrences in the district.

The results of exploration which has extended to a depth of 135 feet on an incline of 15° to 18° indicate that the deposit has the form of a shoot, at least in the upper oxidized portion. Practically all of the ore is comprised within the limits of the shaft workings. In the lowest part, however, the sulphides extend across the shaft on the normal northeast strike and show indications of taking the form of a band or lens in common with the other occurrences. On the surface the continuation of the same lead may be observed by outcroppings of weathered material for a considerable distance northeast of the shaft. At about 1000 feet distant the unaltered sulphides are shown in a shallow working over a width of 12 feet or more.

It would appear that the peculiar conditions encountered in the shaft are the result of purely local influence, and that if the ore continues in depth it will probably change to the ordinary type as exemplified by the other deposits in the vicinity. There has occurred a deep oxidation of the ore, with a secondary migration of some of the zinc from the weathered part of the deposit — a result that can be traced back no doubt to preglacial times. The fact that the iron is in the form of hematite, rather than limonite, indicates a difference of conditions from those obtaining at present where limonite is the single product of weathering. Nowhere else has the process of oxidation continued to such depth and the reconcentration of the zinc been so well defined. In view of all the facts that have been brought to light it seems probable that the deposit originally was of the normal type — a mixture of pyrite and sphalerite in the form of a lens or ban — and that by reason of local fracturing or some other physical feature that favored the process, the ore was subjected to deep oxidation in a circumscribed area. As the result of this oxidation the pyrite was converted into hematite and the sphalerite probably into zinc sulphate which was then partially reprecipitated as sphalerite in contact with the sulphides lower down. The migration of the ores was effected by ground waters working along the dip of the body and their influence is to be seen also in the admixture of vein quartz that accompanies the ore. The weathering and secondary concentration may well have taken place under the cover of the Potsdam sandstone which spread over the area previous to Glacial time.

A little north of the zinc deposit occurs a band of talc which has been explored in recent years. The sulphides occur thus between two parallel talc beds, the main one being to the south on which the Arnold, Wight and Columbia mines are located and which lies on the hanging side of the Balmat-Streeter zinc deposits.

Cemetery lot. This locality is southwest of Balmat Corners and nearly due south of the Balmat mine, close to the border of the limestone belt. The contact of the limestone with the hard formations is quite involved in the section east of Sylvia lake, as shown in the sketch map, but on the south side it sweeps around in a broad curve at a distance of a mile or less from the lake shore. In the stretch southwest of Balmat Corners it lies just south of the Fullerville road. The limestone near the contact is very impure, showing talc and serpentine inclusions and intercalated quartz bands which in many places constitute more than one-half of the mass. Its attitude is difficult to determine, but in general it seems to follow the usual northeasterly course and to dip northwest.

The zinc showing is on the south side of the ridge which crosses the Fullerville road and which is partly occupied by a cemetery. The presence of ore here was discovered by Arthur Scott who performed the little exploration that so far shows a band of rich blende and pyrite near the base of the ridge, with a width of 2 feet or a little more and of undetermined length. The strike is northeast and the dip southwest. On the hanging side a smaller band makes off into the limestone at nearly right angles.

The occurrence has interest, aside from whatever commercial importance may be attached to it, by reason of the evidence of secondary mineral growth in the ore and wall rocks, rarely to be seen in so clearly marked examples elsewhere in the district. The ore band apparently has been a locus of considerable compression and deformation; it is traversed by many fractures in which secondary carbonates, mainly calcite, have been deposited in rhombohedral aggregates. This latter material contains no sulphides. There is a second generation of pyrite which takes the form of large individuals — 2 or 3 inches in diameter — that have one or more crystal boundaries and that are not intergrown with the sphalerite as are the smaller grains of the groundmass. The sphalerite itself has undergone a partial rearrangement, and the stringer of ore in the hanging wall is probably the result of a secondary migration under the same conditions which led to the recrystallization of the ingredients.

The ore is fairly rich and its character is such that it could be easily concentrated.

Rhodes place. Two or three prospects, in which a good quality of ore is revealed, are to be seen on the Rhodes farm near Talcville, directly opposite the Uniform Fibrous Talc Company's mine and mill, just southwest of that place.

Hyatt mine. This is the second property in the district that has been developed to a producing stage and the only shipper of blende concentrates up to the present time outside of the Edwards mine. It is in the vicinity of Talcville, directly southwest of that place along the railroad (station, Hyatt) and on the east branch of the Oswegatchie which flows along the northern boundary of the property. Mining has been restricted so far to the Rhodes, Weed and Weed place, but showings of ore are found on adjoining lands.

The first locations were made here by the Dominion Company of Gouverneur. Prospecting was begun on an outcrop lying on the northwest side of the limestone ridge that marks the approximate site of the main ore zone, where later no. 1 shaft was located. About 3 feet of ore of good quality was exposed below a thin gossan, with a dip to the northwest somewhat steeper than the hill slope. Other croppings occurred on the southeast slope across the summit of the ridge in the footwall of the first. Only trial shipments of lump ore were made by the Dominion Company. In 1918 the Hyatt Ore Corporation took a lease and started to equip the property with mining and milling plant, centering operations upon the deposit opened in no. 1 shaft. Up to the year 1922 when operations were terminated by that company the workings had been carried to a depth of 425 feet, with four levels extending on the strike of the ore. The first level at 150 feet was used as a prospecting drift to test the ground to the southwest of the shaft and was extended a distance of 750 feet. The second and third levels were each 400 feet long and the fourth was 250 feet. Nearly all of the ore milled came from this deposit. On the southwest end of the ridge no. 2 shaft was started to prospect the ground beyond the reach of the prospect drift and particularly to pick up a deposit that shows on the surface directly south of the shaft. On the north side of the ridge no. 3 shaft was put down to test a local outcrop. Minor excavations were also made on the east side of the ridge.

It would appear that the ore occurs in shoots and narrow lenses rather than in laterally extended bodies and that with the complex structures of the limestones they are difficult to define from limited exploration. The low ground to the north and south of the ridge is practically untested and seems to be the most promising section for additional prospecting. Confirmatory of this opinion is the recent uncovering by surface trenching of ore on the south side which was concealed by several feet of boulders and gravel. So far as developed it is one of the best showings in the district.

The limestone outcrops along the ridge bear evidence of local accentuation of the usual metamorphic influence shared by the carbonate materials of the district. They have been largely replaced by silicates — tremolite, talc and serpentine — and in places are seamed by white quartz or contain great masses of the latter. These are the effects, it is likely, of the granite which outcrops along the ridge marking the north side of the limestone belt. On the south side the limestones give way to concordant beds of Grenville gneiss, forming the foot wall of the ore zone. The rocks have undergone considerable pressure deformation so that observations of dip and strike show wide variations and are even obscured by mass flowage of the limestones. In the railroad cut on the northwest side there are evidences of close folding accompanied by a fault. Two rusty bands of limestone seem to mark here the locations of the main ore body tapped by no. 1 shaft with two talc seams overlying them. The strike here is to the northwest which carries the beds to the adjacent river below which they disappear to reappear on the opposite bank where the limestones assume their normal northeast trend.

It may be noted that talc was once mined on the property in a shaft sunk along the hanging side of the zinc body not far from no. 1 shaft. The old workings were encountered in the recent mining.

The ore from the locality is a mixture of blende and pyrite, usually well segregated and showing talc and serpentine inclusions as described for the Edwards occurrence. In the richer samples the carbonates have been largely replaced, but all gradations occur down to limestone with scattered particles of metallic minerals.

A feature of the outcrop of the main vein is the presence in places of a greenish yellow coating on the sulphides, which reacts for cadmium and would appear to be a form of the mineral greenockite. It is of earthy granular texture, not crystallized.

In its milling operations the Hyatt company adopted different methods than those in use at Edwards, following the general scheme of separation employed in the middle western districts. The first concentration was made by Joplin jigs after rather coarse crushing. Tables were used for the final process. No pyrite concentrate was made. The treatment seems to have yielded a satisfactory separation and recovery of the zinc values.

Various minor occurrences. A little prospecting has been performed by Gouverneur interests on the Davis farm, northwest of Pleasant Valley School, in the middle of the limestone belt and nearly south of Talcville. The farm is shown on the contour map at the end of the branch road which connects with the Edwards-Fullerville road just west of the school. The blende occurs as a dissemination within the limestone and as far as explored is of relatively lean character.

On the McGill farm, on the Edwards road from Pleasant Valley School, and just south of the large quartzite ridge, there are scattered bunches and disseminations of sphalerite. Some blasting was done at one locality close by the road about where the latter crosses the 700-foot contour on the map. It failed to show any defined body of ore, although samples were obtainable which carried as much as 10 to 15 per cent zinc. This work was done by Messrs Potter and Finch of Gouverneur.

Disseminated blende and pyrite are to be seen in several places on the Austin farm, northeast of Sylvia lake.

A showing of rich blende, practically free of pyrite admixture, is to be seen directly on the shores of Sylvia lake, partly under water. The occurrence is about one-half mile southwest of the one on the Dominion Company's lands and is reported to be held under lease by the Northern Ore Company.

At the falls on the west branch, about 3 miles above Fullerville and just off the Gouverneur sheet, an occurrence of sphalerite has been reported by J. C. Finch. There is only a small quantity of the ore in evidence, but it has interest as showing the continuation of the limestone in an offshoot of the main belt much farther south than had been supposed.

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Pyrite

Pyrite occurs in the Gouverneur area in two kinds of deposits. In the one the deposits are associated with crystalline limestones and carry both pyrite and sphalerite in such mixtures that their separation is a necessary step in the marketing of the ores. This class of deposits, illustrated by those of the Edwards district, is described under zinc, which normally is the main element of value, the pyrite being considered a by-product. The second type contains pyrite alone, or pyrite in combination with pyrrhotite, but never sphalerite in quantity, and occurs in Grenville schists and gneisses that represent doubtless old sediments of the nature of silts and sandstones.

The pyrite deposits are usually described as veins, but they are really zones within the schists that have been impregnated with the sulphide without reference to secondary fractures or fissures. They seem to compare rather closely to the bedded structure of the wall rocks, whenever this is determinable, and consequently assume a tabular or lenticular form in characteristic development. The sulphide is accompanied by more or less vitreous quartz and may be seen to occur in two forms: as finely divided particles rather evenly distributed through the gangue, and as aggregates of coarser particles and crystals in bunches, veinlets and stringers more irregular in their distribution. Some of the ore contains little else than fine granular pyrite in a gangue of quartz, feldspar, mica and chloritic alteration products. In other examples the ore is a network of small bands and stringers which intersect the gneiss or else consists of an alteration of the sulphide bands with layers of the rock, presenting a coarser appearance than the ore in which the pyrite is evenly disseminated and also as a rule containing a higher content of sulphur. The coarse ores carry 25 to 35 per cent, whereas the finer, disseminated variety is usually under 25 per cent in sulphur.

Some pyrrhotite may be present in the ores, not intermixed with pyrite generally but in separate aggregates that occupy a particular position, such as one or another of the walls of the orebody. Independent bodies of pyrrhotite are also found in the area. On the whole, however, it is much less common than pyrite. In sulphur content the pyrrhotite ores are practically on a parity with the others, notwithstanding the considerable difference in chemical proportions of sulphur and iron in the two minerals.

The deposits show marked persistence along their strike, and where they have been mined underground they have been found to persist in the direction of their dip or pitch as well. Their thickness, however, is small compared with the other dimensions. In most places they are not more than 15 to 20 feet thick from wall to wall, and 40 or 50 feet represents the very extreme, while they may be followed along the trend on the surface for several thousand feet and the ore zones are traceable for miles.

The pyrite deposits of the region have been described by A. F. Buddington[1] from whose report the following abbreviated account of the occurrences within the Gouverneur quadrangle has been in part compiled.

Cole mine. One of the more important pyrite occurrences is on the J. Frank Cole farm, 5 miles northeast of Gouverneur, close to the R., W. & O. railroad. It has been worked intermittently for the past 15 years, contributing a small output of lump ore, and has come into the hands of the New York Pyrites Company. A mill is

[1] N. Y. State Defense Council Bul. 1. Albany, N. Y. 1917.

now (1919) in course of erection which will enable shipments to be made in the form of high-grade concentrates.

The shape of the ore bodies at this locality shows a marked departure from the simple form that characterizes most of the deposits in the district. Its precise structure, however, has not yet been fully determined. In the early operations two veins were encountered, on one of which the shaft was sunk 222 feet in 15 to 18 feet of ore with a northwest strike. On the hanging side, separated by 15 feet of schist, was another body which was followed for 90 feet in a northeast direction and for 60 feet at right angles thereto. It developed from later work that the vein in which the shaft is located and the overlying vein are connected on the northwest side by an ore band 10 feet thick. It seems probable that the ore has been subjected to compression and folding, but further developments must be awaited to determine whether this is actually the case. Recently a series of prospect pits put down between the mine and the highway showed the continuance of the pyrite to the east with a probable thickness of 30 feet.

The ore is conspicuously banded, showing alternate layers of coarse pyrite and fine pyrite admixed with schist. Some specimens are practically pure sulphides, and the average is well above the mean of most deposits. The lump ore as shipped contained 30 per cent or more sulphur.

Ore Bed School prospect. This is in the northeastern part of the quadrangle, 3 miles south-southeast of East De Kalb, town of Hermon. The ore occurs in a belt of rusty gneiss that extends northeast and probably connects with the Stella mines near Hermon village. Two veins are exposed on the hill one-fourth of a mile north of the school and have been prospected in a small way. They show ore of about the same quality as that of the Stella mines, but of uncertain thickness; the property would merit investigation if there was a market for material of this grade. Hematite was once mined in the vicinity, the deposit occurring in the same gneiss belt as the pyrite.

Farr prospect. This is situated in the town of De Kalb, 3 miles northeast of Bigelow, on the farm formerly owned by Alexander Farr and more recently by Henry Fleming. A vertical shaft was started in 1904 but was not continued to any considerable depth. About 6 feet of ore is shown in the shaft, mostly pyrrhotite, with a vein of pyrite on the east side. Another ore vein occurs to the west of the shaft, separated by 6 feet of gneiss, and is not well exposed.

There are evidences of folding, but the structure is uncertain. A prospect 50 yards north of the shaft shows 9 feet of pyrrhotite. The gneiss is bordered east and west by limestone and shows a width on the surface of 200 feet. Typical samples of the pyrrhotite ore contained 20.87 per cent sulphur and .22 per cent arsenic.

Mitchell prospect. This is located on the Calvin Mitchell farm, about 3 miles northeast of Bigelow, town of De Kalb. The ore zone, as shown in a prospect shaft, is 7 or 8 feet thick, consisting of pyrite with a band of pyrrhotite in the middle. The walls are injected Grenville gneiss. Samples gave about 24 per cent sulphur and .16 per cent arsenic.

Styles prospect. This is on the farm of D. G. Styles, 2 miles northeast of Bigelow. The vein is about 9 feet thick where exposed in the shaft opening, but contains intercalations of gneiss.

Hendricks prospect. In the town of De Kalb and 8½ miles southwest of Bigelow, near where the railroad crosses Boland creek is a vein that varies from 2 to 10 feet thick and is sheeted, so that the average is rather lean.

Pleasant Valley School prospects. A hill of rusty gneiss is a rather conspicuous landmark on the road from Edwards to Fullerville, just north of Pleasant Valley school. Some attention has been given to the uncovering of bands or veins of pyrrhotite that intersect the ridge and that average very high, in that mineral. The veins seem to be small.

Kilburn prospect. This prospect is in the belt of Grenville gneiss that borders the Sylvia lake limestone area on the north and west. There are no well-defined bands or veins and the ore consists mainly of disseminations of pyrite and pyrrhotite in fine grains, somewhat richer than the average of the country gneiss.

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Talc

Talc is perhaps the leading mineral product of the Gouverneur district. It has contributed directly about $18,000,000 in actual value since the beginning of production, and indirectly has been the means of introducing other industries for the utilization of the natural resources of the region, notably water power enterprises which are an essential factor in the economic production of ground talc.

The mining of talc has been in progress for more than 40 years — since 1880 without interruption. The total output may be placed in round numbers at 1,900,000 tons with a value that quite equals the figure above given. The product, which has special characteristics that make it indispensable in many manufacturing industries, finds a market all over the country, and under normal conditions in foreign lands as well. Although Gouverneur has given its name to the material as identifying the source or grade, the mining localities are several miles from the village in the towns of Fowler and Edwards. Gouverneur, however, is the general center for the management and operation of the mines and in early years was the shipping point. The Gouverneur and Edwards railroad now serves the district, being used to bring the talc from some of the mines to the mills for grinding and also for the shipment of the finished talc.

Nature and uses. Talc is a mineral of variable habits and qualities, and its uses vary with its characteristics. Chemically, it is all one and the same material — hydrated magnesium silicate. It occurs in two general forms: as a primary deposit from solution, and as a secondary product that results very commonly from local alteration of an anhydrous magnesium silicate, such as tremolite and enstatite. Primary talc has a scaly or foliated habit, like mica in appearance, has certain definite physical properties, and in chemical composition comes close to the proportions demanded by the formula, that is, silica 63.5 per cent, magnesia 31.7 per cent and water 4.8 per cent. Secondary talc has no well-defined physical structure but adopts the structure of the mineral from which it has originated, granular, fibrous or massive, as the case may be. It is likely to be somewhat impure, varying with the conditions, and particularly to contain unaltered remnants of the parent substances. When massive and coherent so that it may be quarried in blocks which are then wrought into various shapes, it is called soapstone.

The purer sorts of foliated, fibrous and granular talc are employed for grinding. Color, texture and degree of softness (freedom from grit) are the natural qualities of most importance. But to them must be added the degree of fineness produced in the grinding operation. For many purposes fine grinding is very essential. One of the main functions of the Gouverneur mineral — which is mostly of fibrous habit — has been as filler in paper manufacture, for which softness and pliancy are requisites. It is said to be retained by the pulp much better than clay, owing to its fibrous nature. The manufacture of rubber consumes large quantities. It is employed also in paints and distempers, as an ingredient of wall-plasters, for electric and heat insulating materials, artificial stone, and many other purposes. There are few minerals that compare with talc in its manifold applications.

Occurrence. The productive talc area is defined by the belt of Grenville limestone in the southwestern corner of the map. The talc occurs in lenticular and sheetlike bodies, which are commonly referred to as veins, within the limestone belt from Sylvia lake to Edwards, a stretch of about 10 miles. The individual bodies conform in structural features with the limestone, having normally a northeast-southwest trend on the surface, but showing minor plications, crumplings and small faults that seldom are observable in the limestone. The dip of the deposits is to the northwest, between 30° and 60° generally, in some instances at still higher angles, varying from point to point with the rolls that appear in every mine.

A lenticular form is most common, although every variation from that type may be found. In thickness the bodies seldom exceed 30 or 40 feet in the widest part, measured from roof to footwall, while the horizontal length as indicated by the mine drifts may be 1000 feet or more. There is no known limit of the talc in depth; the deepest mines are 700 to 800 feet along the dip and no decided change in the deposits with regard to character of the material has been noted within that distance.

The talc bodies are distributed along the borders of the limestone and although they occur rather irregularly, most of the mines are grouped in two main belts extending northeast-southwest parallel with the limestone-gneiss contact. One of these lies on the north side of the limestone area in the vicinity of Talcville. It contains the mines of the Uniform Fibrous Talc Company on the Oswegatchie river below Talcville, the old United States mine at Talcville, and the several openings of the International Pulp Company including nos. 2½, 3, 4, and 5 in the stretch between Talcville and the first mile northeast of that village. It is not uncommon to find two or more layers of the talc in overlapping arrangement in this section. The bodies are separated from each other by beds of unchanged tremolite or by limestone. In some instances the talc has both foot and hanging walls of tremolite schist, although more generally limestone forms one of the walls.

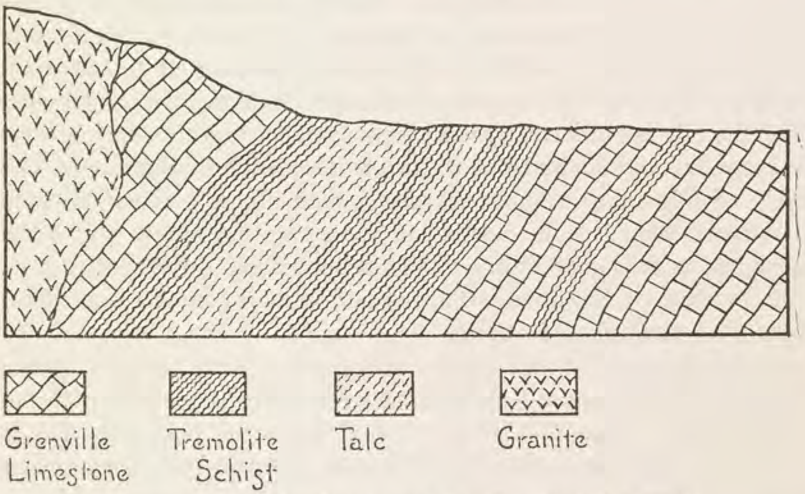

Figure 16 Generalized section of the Edwards talc deposits

The second group of mines lies in the southwestern part of the limestone area and on the southern margin to the southeast of Sylvia lake. Here are the Balmat, White and Arnold mines, recently operated by the International Pulp Company, the mine formerly worked by the Ontario Talc Company near Fullerville, and also the shafts and prospects on the property of the Dominion Company just east of Sylvia lake. This belt is about 3 miles long and the talc occurs within a short distance of the footwall which consists of a dark amphibolitic rock injected by red granite. In this area there is more or less foliated talc associated with the fibrous variety, occurring in small seams which intersect the foliated talc or occupying more or less independent bodies.

Altogether there are nearly twenty mines and prospects in the district, but only a few of these have been actively worked in recent years. Only the more important, including those under recent operation, will be described in this place.

Talcville mines. One of the principal producers in this section has been no. 2½ mine at Talcville, the property of the International Pulp Company. It is located on a seam of talc which lies on the north side of the limestone belt not far from the granite contact, the same seam that has been opened in the United States mine to the southeast, and probably has its continuation in nos. 3, 4 and 5 mines to the northeast of Talcville. The mine is opened by an inclined shaft which has now reached a depth of nearly 700 feet on the dip. The principal seam that has been exploited ranges from 4 or 5 feet to 30 feet in thickness. It starts on the surface with a dip of 45° to the northwest and steepens at the 600-foot level to 80° which dip is maintained to the bottom. On the hanging wall the talc is bordered by hard tremolite schist, within which there is more or less talc, and this in turn is succeeded by limestone. The body of talc shows numerous rolls and in places pinches down to a narrow seam; at the north end it swings around to the north owing to a fold and is practically squeezed out in that direction. The product of the mine is fibrous talc with practically no admixture with the foliated variety.

The outcrop of the talc body disappears a little distance to the northeast of the no. 2½ mine where the ridge is succeeded by an alluvial flat. Beyond this low ground the ledge reappears and is opened by the no. 3 shaft, a considerable producer of talc in former years. Next in order is no. 4 mine, one of the active properties of the International Pulp Company. This mine is also opened by an inclined shaft and has reached a depth of over 400 feet. The levels have an extreme length of 900 feet. Two parallel bodies of talc are exposed in this vicinity with a parting of tremolite schist. On the hanging side of the talc that has been worked by no. 4 shaft, is hard unaltered schist, then limestone and finally granite. On the footwall of the talc occurs a soft, clayey seam, a few inches wide, which is water soaked. No. 5 mine, next northeast of no. 4, marks the apparent limit of the talc in that direction. The mine has been closed down for several years and little is known about the underground workings.

Adjoining no. 2½ mine on the southwest is the mine formerly worked by the United States Talc Company which ceased operations in 1906. It is based on a continuation of the same seam, with conditions very similar to those described for the former mine.

The upper workings left by the operations previous to 1906 subsequently caved, rendering them inaccessible from the surface. The property recently has been acquired by the International Pulp Company and is being worked in conjunction with no. 2½ mine through drifts from this shaft below the caved area. It is one of the main sources of supply of that company.

The mine of the Uniform Fibrous Talc Company is situated a little southwest of Talcville along the east branch on a slight prominence known as Wintergreen hill. The main shaft, the one first opened, is close to the river. The company began operations in 1911 and the mine was practically a new development from the surface. On account of insecure conditions for mining the first shaft was abandoned after reaching a depth of 350 feet, and a second one was sunk on the hanging side about 200 feet distant. This tapped a new deposit by means of a cross-cut at the 130-foot level. The development of the second seam had not proceeded very far when the company ceased work, having lost its hydro-electric station at the Sullivan dam on the west branch through a washout. The last operations were in June 1921. The product was of good quality and amounted to 30 to 40 tons a day.

Sylvia lake district. The progress of mining in this part of the district has been retarded somewhat by the lack of shipping facilities, it being necessary to haul the lump talc several miles to reach the mills which are situated along the Oswegatchie river. The talc is of excellent quality, but differs from the general run in the northeastern section in having a greater proportion of scaly mineral. The two kinds are so segregated, however, that the grade of the mill product can be controlled. The foliated talc yields a very soft product, which when finely ground commands a special market.

The Balmat mine is in the extreme southwest end of the district as at present developed, about one-half mile east of Sylvia lake. It is on the road running from Fowler to Balmat Corners, with Emeryville on the Gouverneur-Edwards railroad as the nearest shipping point. The mine has been worked through an incline which starts at an angle of 27° but steepens toward the bottom. The main levels extend about 1000 feet on the course of the deposit, northeast-southwest, and the talc measures 30 to 40 feet from wall to wall in the widest part. On the hanging side of the seam occurs a band of from 6 inches to 3 feet of foliated talc, clear white and free of impurities, the rest being the fibrous variety pseudomorphic after tremolite. The mine is one of the main sources of rock for the International Pulp Company which hauls the output to Hailesboro for grinding.

The Dominion Company owns deposits, not at present mined, on the north and west sides of the Balmat next to the lake. Some development work has been done on them but active mining must await the construction of a mill to handle the output.

The Wight mine is northeast of the Belmat and about one and one-half mile south of Fowler. Its output is handled by the International Pulp Company.

The Arnold mine, a little northeast of the latter, is one of the old Union Talc Company's properties and was taken over by the International Pulp Company when that company went out of business. It is now owned by the W. H. Loomis Talc Corporation, having been acquired in 1919 and since operated by this company for supply of its new mill at Emeryville. It is opened to a depth of 300 feet with levels that extend about 500 feet along the axis of the seam. Like the other deposits of this section, it contains both fibrous and foliated grades, with some long-fibered material. It is likely to prove one of the largest producers in the district under the new management which has plans under way for a large increase in its milling operations.

Fullerville. There are several prospects in this vicinity and one mine, now inactive, that has been quite extensively worked, the property of the former Ontario Talc Company. This is located about 1 mile below Fullerville beside the west branch. The deposit is probably not connected with either the Talcville or the Sylvia lake areas, being separated from the former by about 2 miles of limestone in which there are no developed bodies, and from the Sylvia lake region by an unbroken mass of amphibolite. The mine was last worked in 1917, in which year the mill at Fullerville of the Ontario Talc Company was burned. At that time the deposit was opened by three levels reached through a slope driven at about 45° angle following the dip. The talc measured from 12 to 18 feet between walls, not including offshoots into the hanging which in places increased the working thickness. The rock consisted mostly of short fiber, with a little admixture of foliated and longer fiber. The company produced about 20 tons a day of ground talc.

Milling of talc. Mills for reducing the talc to a pulverized condition have been built at various places along the Oswegatchie river from Talcville and Fullerville to Hailesboro 3 miles east of Gouverneur. Their location was determined usually by local water powers. In recent years transmission lines have made possible the centralizing of milling operations at more advantageous points and there are fewer plants now than formerly.

The methods employed in the reduction process have changed much in late years and innovations are still being made. While talc is one of the softest of minerals, its comminution to the state of fineness demanded by most trades is a laborious if not a difficult operation, in which opportunity is given for constant improvement. The present system or systems represents a gradual development extending over the whole period of the industry. The earliest method consisted in grinding in buhrstones similar to those used in flour mills, but now the reduction is accomplished in several stages by special types of machines, each adapted to the particular operation for which it is used.

Until a few years ago the common mill equipment consisted of a crusher for breaking the mine rock, followed by an intermediate crusher, from which the product went to a revolving drum or conical mill, and then to a cylinder where the final reduction was accomplished. The latter was usually the Alsing cylinder, with Danish pebbles for grinding medium, and the talc was retained in the cylinder until the desired degree of fineness was reached. This represents the so-called batch process. It has the disadvantage of not being continuous in operation. A later development consisted in the replacement of the cylinders by long tube mills with continuous discharge. In one of the largest mills the material is taken directly from the crusher into such a tube mill, the discharge going to a second mill, this to a third, and the final reduction made in a fourth mill, the flow being continuous from one to the other.

Along with improvement in grinding has come an increasing demand for the finest sizes of ground talc. At one time the general run of product ranged from 100-mesh to about 200-mesh, the latter being about the minimum limit reached in grinding. Much of the demand now calls for 300-mesh material or finer. This has necessitated the incorporation of additional equipment for sizing the talc which formerly was carried out by screens and bolts. About the only practical means of doing it is by air flotation. In the latest designed mills each stage of reduction is accompanied by air separation so as to by-pass the fine material from the succeeding steps and to provide uniform sizing for the whole product. This has been the greatest advance of the milling process reported in recent years, as it enables a greater output to be made by the same crushing equipment and tends toward an improved product. The air separator effects the removal of much of the hard particles, quartz and mill grit, which have been something of a handicap to the use hitherto of the talc from this district for certain purposes.

A distinct grade of Gouverneur talc is buhrstock, made from the selected fibrous rock by omitting the final reduction, the process being carried only so far as to give a thoroughly shredded material of the texture of short-fiber asbestos. It has been made in restricted quantities of late years, although once a regular product of the mills. Its uses were mainly in insulating materials and prepared plasters.

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Feldspar

The abundant development of pegmatite in connection with the main granite intrusions of the district has already been commented on in the description of the geological features of the area. The occurrences individually are seldom of large extent, but they are widely scattered and not infrequently follow in close sequence so that they constitute a rather important element of the physical structure when taken in their entirety. They exhibit a good deal of variation in their make-up, particularly with reference to the feldspar. This may be one of several species and the proportions may range from nearly solid feldspar aggregates to those in which the mineral is quite subordinate to the quartz. Dark silicates usually are of little importance, although black tourmaline is a persistent and occasionally a prominent ingredient. In most of the pegmatites examined the feldspar has proved to be microcline or an intergrowth of microcline with albite, but an acid plagioclase of the type of oligoclase is not uncommon as a minor component. The color of the microcline ranges from pure white to creamy white, occasionally being pink or red. The plagioclase is white or greenish; the quartz is usually milky white. Mica and hornblende are dark ingredients additional to tourmaline.

Within the limits of the map the principal occurrence for the production of pottery spar is on the Kilburn farm, town of De Kalb, between Bigelow and De Kalb Junction. It has been worked for several years by the Green Hill Mining Company, Inc., with office at Gouverneur. The feldspar is white microcline intergrown with albite, occurring in well-segregated crystals that measure from 5 or 6 inches to 3 feet long. Iron is practically absent, in which respect the product is superior to most of the material on the market. The pegmatite body has the shape of a lens with the major axis running northeast-southwest and a steep or nearly vertical dip. The workings consist of both open and underground quarries. There is little waste and this mostly quartz which is removed by hand cobbing. The lump spar is hauled to De Kalb Junction for shipment and is sold to grinders at Trenton, N. J. and other points for use in pottery.

In view of the increasing scarcity of high-grade spar in the eastern markets, systematic prospecting within the Gouverneur and surrounding districts would seem to be well worth while. The porphyritic granite of this region shows a well-marked tendency to develop pegmatite phases and its usual low iron content is favorable to the occurrence of spar with a minimum admixture of the dark silicates that are the bane of most quarries.

Reference. Newland, D. H. Quarry Materials of New York. N. Y. State Mus. Bul. 181, 1916.

QUARRY STONES

The quarry stones available for use within the area are limestone, granite, and various gneisses that range from light granitic rocks to dark gabbroic varieties. Potsdam sandstone outcrops in several places, but the ledges are usually small, scarcely substantial enough to form the basis for systematic quarry operations like those carried on around Potsdam in northern St Lawrence county.

Limestone and Marble

The crystalline limestones of the Grenville belts are sources of building and monumental stone, furnace flux, crushed stone and stone for lime burning. The purer, more substantial beds have been quarried extensively for structural stone, examples of which are to be found in many of the churches and public buildings of northern New York and in other parts of the State, and also for polished work or marble of which the Gouverneur marble is a good example. The principal quarries are located along the Gouverneur-Richville belt and most of them in the vicinity of Gouverneur.

The limestone in general is medium to coarse crystalline and white or light gray in color, but sometimes is a dark blue shade as in one or two of the Gouverneur quarries. It is normally a calcite limestone with a varying, although small, percentage of magnesia. The carbonates amount to about 95 per cent of the whole mass, so that it ranks as one of the purer limestones to be found in the State. In a few places the magnesia increases to such proportion that the rock may be characterized as a dolomite. The change from calcite limestone to dolomite takes place abruptly, but whether it reflects an original variation in conditions of deposition or is due to a secondary process after the strata were laid down, is not clear. In the former case it would be expected that the variation should be related to the bedded structure, but such relation can not be definitely established. The occurrence of dolomite is quite local and unimportant as compared to the great body of calcite limestone.

The Gouverneur marble is quarried from a small area southwest of that town. The quarries, with few exceptions, lie along a narrow belt which extends for over a mile in a northeast-southwest direction. They lie on the outcrop of the " vein " or bed which dips northwest at an angle ranging from 15° to 30° on the northeast end to 80° to 90° in the southwesterly quarries. The vein has a pitch that is toward the southwest at an angle of 20° or 25°. In color it is a mottled white and grayish blue, or light and dark blue stone, running occasionally to an almost solid dark blue, which is the tint most sought for. In the lighter mottled sorts, the grain is coarse, with the lighter and darker particles segregated more or less into separate areas. The individual calcite particles mostly have a diameter of 1 to 2 mm. In the dark blue marble the grain is much finer, the calcite averaging only a fraction of a millimeter. The bluish color seems to be traceable to the presence of graphitic carbon in very small submicroscopic particles. Free carbon has been detected in chemical analysis of the stone, but in too small amounts to be separately weighed. That the variation of color conforms more or less closely to the bedding is evident from a study of the relations revealed in the different quarries. The lighter colors are found in the higher beds of the northern section, and the dark blue marble is found in the lower beds of the southwest. This relation has been established clearly by results of drilling.

The limestone from the Gouverneur area is susceptible to high polish, which together with its attractive luster and good texture has given it considerable favor as a monumental stone. For building purposes it is mainly used in rock face ashlar, of which the color is a medium gray; on cut or hammered surfaces the color is considerably lighter.

Among the quarries in the Gouverneur district that have yielded building and monumental marble are those of the Gouverneur Marble Company, the St Lawrence Marble Quarries, the Northern New York Marble Company, and the Callahan quarry, all situated in the area from 1 to 2 miles southwest of Gouverneur. In the past few years the principal producer has been the Gouverneur Marble Company. A mile distant from the main group of quarries is the Rylestone quarry on a low ridge nearly due west of Gouverneur and south of Natural Dam. The quarry site is just off the limits of the Gouverneur sheet. The marble is bluish gray with a mixture of white and blue calcite. It is owned by J. J. Sullivan of Gouverneur.

A white dolomite has been quarried for building stone in the vicinity of Peabody Bridge, 2 miles north of Gouverneur. The stone has a coarse texture and is clear white. Analysis indicates a nearly pure dolomite. It was once worked by the White Crystal Marble Company and has been operated in a small way by J. J. Sullivan.

In the vicinity of Richville are many limestone quarries which have been worked at one time or another in connection with limeburning plants, also for crushed stone and furnace flux. One of the larger quarries is about 2 miles south of Richville station close to the R. W. & O. railroad tracks. It was operated for a number of years by Corrigan, McKinney and Company.

White dolomitic marble occurs also in the town of Fowler; extensive exposures are found on the Abbott farm just west of the Fowler post office. It has been worked in a small way principally for making artificial building stone.

Analyses of Gouverneur Marbles

	1	2	3	4	5
Insol	3.55	1.26	1.01	.....	.....
SiO_2	.....	.....	.....	1.58	.28
Al_2O_3	.13	.65	.23 }	.79	.10
Fe_2O_3	.08	.29	.63 }		
MgO	.....	.....	.....	3.49	20.64
$MgCO_2$	6.40	7.50	6.85	.....	.....
CaO	.....	.....	.....	51.45	31.45
$CaCO_3$	87.06	87.47	88.94	.....	.....
H_2O	1.68	1.46	1.74	.....	.....
CO_2	.....	.....	.....	42.56	47.38
S	.05	.02	.04	.03	.06

1 Sample from the extra dark quarries of the St Lawrence Marble Quarries. R. W. Jones, analyst.
2 Quarry of the Gouverneur Marble Company. R. W. Jones, analyst.
3 Rylestone Quarry. R. W. Jones, analyst.
4 Northern New York quarry.
5 Dolomite near Peabody Bridge.

Granite and gneiss. The common granites of the area have a red or pinkish color and are composed of feldspar, quartz and some dark silicates like hornblende and biotite. They are developed over extensive areas but only in a few places are they unmixed with Grenville rocks, so that usually they are not well adapted for architectural stone. They afford, however, a wealth of material suitable for road making and foundation purposes. The same is true of the gneisses, some of which are merely granite-injected members of the Grenville schist series, variable in habit and durability, but as a rule substantial enough for all ordinary purposes. The amphibolites afford a dark stone that is especially serviceable as crushed stone for road making on account of their tough well-knit character, a feature imparted by the abundance of hornblende.

No permanent quarries have been opened in the granites and gneisses within the Gouverneur or surrounding area. Road improvement has called for a considerable production of crushed granite, but as the requirements could be supplied usually from sites close at hand operations have nowhere been carried on on a large scale.

References. **Merrill, F. J. H.** Mineral Resources of New York. N. Y. State Mus. Bul. 15, 1895.

Newland, D. H. Quarry Materials of New York — Granite, Gneiss, Trap and Marble. N. Y. State Mus. Bul. 181, 1916.

Smock, John C. Building Stone in New York. N. Y. State Mus. Bul. 10, 1890.

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Geologic Map of the Gouverneur Quadrangle

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STATE MUSEUM

BULLETIN 259
GOUVERNEUR QUADRANGLE

R. B. Marshall, Chief Geographer.
Frank Sutton, Geographer in charge.
Topography by J. M. Whitman, S. P. Floore, Roscoe Reeves, and E. E. Witherspoon.
Control by C. B. Kendall and A. J. Kavanagh.
Surveyed in 1912 and 1913.

SURVEYED IN COOPERATION WITH THE STATE OF NEW YORK.

Scale $\frac{1}{62500}$

Contour interval 20 feet.
Datum is mean sea level.

APPROXIMATE MEAN DECLINATION 1912.

Geology by H. P. Cushing,
1916-17.